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CONTENTS

CONCERNING THE MUTATION THEORY. PROFESSOR T. H. MORGAN . . . 385

THE APPLICATION OF ORGANIZED KNOWLEDGE TO NATIONAL WELFARE. DR. P. G. NUTTING 406

THE WORK OF MUSEUMS IN WAR TIME. DR. HARLAN I. SMITH 417

THE ALSACE-LORRAINE QUESTION. DR. C. C. ECKHARDT 431

BEEKEEPING AND THE WAR. DR. E. F. PHILLIPS 444

HOG CHOLERA: ITS ECONOMIC IMPORTANCE AND PREVENTION. DR. R. R. BIRCH. 450

DOES CROP ROTATION MAINTAIN THE FERTILITY OF THE SOIL? J. E. GREAVES 458

THE INTERRELATIONS OF ANIMALS AND PLANTS AND THEIR INFLUENCE UPON THE FOOD SUPPLY OF MAN. PROFESSOR ROBERT W. HEGNER . . 467

THE PROGRESS OF SCIENCE:
The Armored Dinosaur; The Sulphur Situation in the United States; War Work of the U. S. Coast and Geodetic Survey; Reconstruction of Crippled Soldiers; Scientific Items 475

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THE SCIENTIFIC MONTHLY

MAY, 1918

CONCERNING THE MUTATION THEORY

By Professor T. H. MORGAN

COLUMBIA UNIVERSITY

THE mutation theory of evolution has met with a stormy reception, despite the fact that De Vries, and most of its supporters, have avowed themselves adherents of the doctrine of natural selection. Some of the older followers of Darwin have insisted that the large steps, which they still believe are the only kind that the mutation theory postulates, could not give the small continuous stages through which evolutionary changes take place. Now, the mutation theory has never made any such "large" claims. On the contrary, it has been pointed out repeatedly that the mutational changes may be extremely small. The theory does claim that the genetic factors are discontinuous, although the characters that they stand for may or may not be discontinuous. De Vries himself has said in the "Mutation Theory" (Vol I, page 55): "Many mutations are smaller than the differences between extreme variants," meaning by the latter term fluctuating variations, pointing out by way of illustration that the constant species of *Draba verna* "differ less from each other than do extreme variations in the same characters." While De Vries's work on the evening primrose, *Œnothera Lamarckiana,* is generally conceded to be the starting point of the modern mutation theory, nevertheless, the peculiar way in which Lamarck's primrose produces its new and recurrent types, which De Vries regarded as the real mutative process, has been difficult to harmonize with the way in which practically all other forms give rise to mutants.

The genetic behavior of the evening primrose is so well known that it is superfluous to describe it here in detail, especially since we are, for the moment, more concerned with the critical treatment of the results than with their exposition. It

will suffice to recall that De Vries found an escaped European garden plant known as *Œnothera Lamarckiana* that produced new types in sufficient numbers to furnish numerical data of unusual value. Some of these new types bred true, although some of them continued to give further evidence of "mutation." Immediately the question arose: Is *O. Lamarckiana* a wild species, or a product of hybridization; and if the latter, is not its mutation process only the resolution of the hybrid into its components? The search for the wild type in America led practically to failure, but the search led to the important discovery that other wild species of the same and related genera were also mutating. Into the vexed question as to whether most or all wild types may not themselves be hybrids, it is not necessary to enter here; for if the point of view that I wish to present is correct, the behavior of *O. Lamarckiana* would be outwardly nearly the same whether it arose by the union of two species, each bearing lethals, or whether its present "balanced lethal" condition arose within the plant itself, no matter what its origin may have been.

That the situation in *Œnothera* is complicated will be clear, I think, to any one who has followed De Vries's latest work "Gruppenweise Artbildung," Davis's experiments with forced germination, Geerts, Gates and Lutz in their cytological work, Stomps and Bartlett on mutability in other species of the genus, MacDougal, Heribert-Nilsson, G. H. Shull and Honing in their analytical work on the genetics of *Œnothera*.

Recently a case apparently similar to the mutation phenomenon of *Œnothera* has been worked out on the fruit fly, *Drosophila melanogaster*, by Dr. H. J. Muller, which, I venture to think, gives us the clue that we have needed so long to show what takes place in Lamarck's evening primrose when it throws off, in definite percentages, characteristic mutant types. This evidence makes it not improbable that this type of behavior of *Œnothera* may be due to the presence in it of *lethal* factors, so closely linked with recessive factors, that only when the linkage is broken do the recessive factors come to light. Here we have a remarkable situation, one that would have seemed, *a priori*, highly improbable, but now that we can at will make up stocks that give the same kind of results as does *Œnothera* the behavior of this plant can be brought into line with mutation, as seen in other animals and plants.

The history of the discovery of a balanced lethal stock in *Drosophila* and its interpretation by Muller is as follows: An

early observed mutant of the fruit fly, *Drosophila* had Beaded wings. Beaded stock was bred for several years, and persisted in throwing some normal offspring. Selection produced no advance until suddenly a time came when Beaded no longer threw any normals; or so few as to be negligible. Why had it not been possible to make pure the stock in the first instance? And what happened when it became pure?

Muller took up the work at this stage and has solved the problem as follows: He found that the factor for Beaded is dominant for wing character, but lethal in double dose. As in the case of the yellow mouse, only the hybrid (heterozygous) combination exists, and consequently when two Beaded flies mate they produce two Beaded to one normal fly, as shown in Fig. 1. Here the first pair of vertical lines stand for the pair of third chromosomes present in the egg before its reduction. The two factors here involved, that for Beaded and its allelomorph for normal, are indicated at the lower end of the vertical lines. The two corresponding chromosomes in the male are represented to the right of the last. After the ripening of the germ cells each egg and each sperm carries one or the other

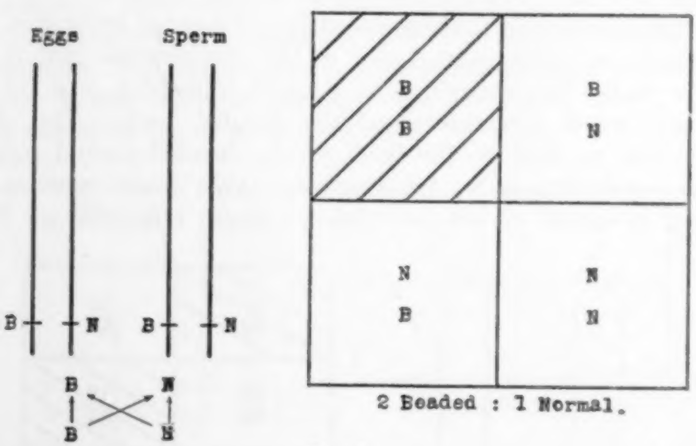

FIG. 1.

of these chromosomes. Chance meetings of egg and sperm are indicated by the arrow-scheme below in the figure, which gives the combinations (classes) included in the four squares. The double dominant BB is the class that does not come through. The result is two Beaded (heterozygous) to one normal fly.

The Beaded stock remained in this condition for a long time; although selected in every generation for Beaded, it did

not improve, but continued to throw 33 per cent. of normal flies. Then it changed and bred nearly true.

The change must have been due to the appearance of another lethal factor (now called lethal three or l_1 in the diagram), because a gene for such a lethal was found in the race when studied later by Muller. The lethal factor is recessive; it is fatal when in double dose. It behaves as do other lethals which Bridges and Sturtevant especially have demonstrated to be frequently present in *Drosophila*. In fact, lethal factors appear to be the commonest type of mutation, which is not surprising when one recalls that most of the mutants are deficient types, whose defects, carried a step further, would in many cases be fatal to the individual. It is only in this sense that the term lethal factors is used by us. They are not supposed to be poisons or any special kind of modification, but only factors that cause some structural or physiological change of such a sort that the individual does not begin its development, or, if it does, it perishes somewhere along the road. In fact, we have lethals that affect the egg stages, the larval and pupal stages, the newly hatched flies, and semi-lethals that weaken the adults, although they do not necessarily kill.

The lethal gene that appeared in the Beaded stock was also in the third chromosome, and in the chromosome that is the mate of the one carrying the gene of a Beaded, *i. e.*, in the *normal* third chromosome of the Beaded stock. The lethal gene lies so near to the level of the Beaded-normal pair of genes that almost no crossing-over takes place between the levels occupied by the two pairs. These relations are illus-

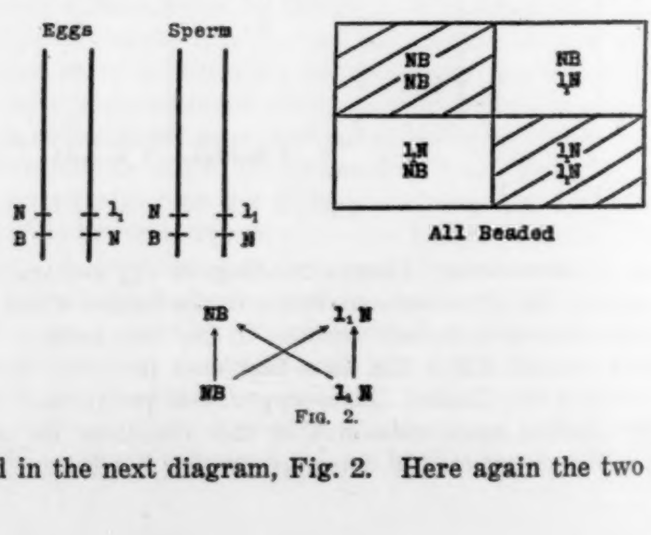

FIG. 2.

trated in the next diagram, Fig. 2. Here again the two pairs

of vertical lines to the left represent the two third-chromosome pairs in the female and to the right the male. The location of the two pairs of genes involved, N — l_1 and B — N, are indicated. These combinations give the four classes in the squares, of which two classes die, viz., NNBB (pure for Beaded) and l_1l_1NN (pure for lethal three). The result is that only Beaded flies come through, and since all these are heterozygous both for B, and for l_1 the process is self-perpetuating.

If the preceding account represented all of the facts in the case, the stock of Beaded should have bred perfectly true, but it has been shown in *Drosophila* that crossing-over between the members of the pairs of genes takes place in the female. Hence we should expect a complication due to crossing-over here unless the level of the two pairs of genes was so nearly the same as to preclude this possibility. In fact, in addition to the Beaded flies the stock in this condition would give 10 per cent. of crossing-over, *i. e.*, it would still produce a small percentage of normal flies. It so happened, however, that there was present in the stock a third gene that lowers the amount of crossing-over in the female to such an extent that, for the two "distances" here involved, practically none takes place. When it does a normal fly appears, but this is so seldom that such an occurrence, if it happened in a domesticated form of which the wild type was unknown would be set down as a mutation like that shown by the evening primrose.

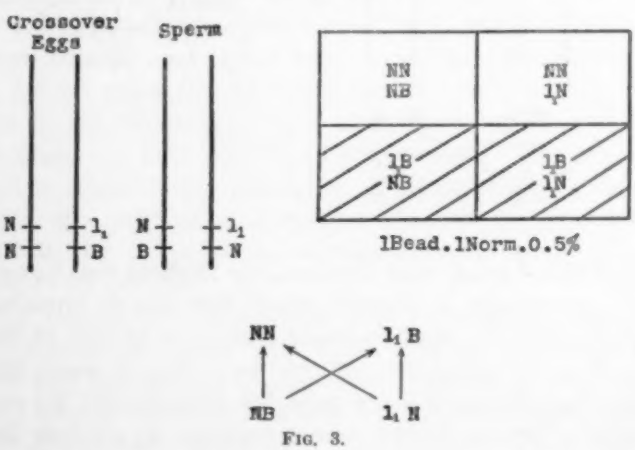

FIG. 3.

The third factor that enters into the result is not unique, for Sturtevant has shown that crossover factors are not uncommon in *Drosophila*. The analysis that Muller has given for

Beaded, while theoretical, is backed up by the same genetic evidence that is accepted in all Mendelian work. It makes an assumption that can be demonstrated by any one who will make the necessary tests. Lest it appear, however, that this is a special case depending upon a very unusual situation, let me hasten to add that with the material that we have in hand it is possible to produce at will other balanced lethal stocks that will "mutate" in the sense that they will throw off a small predictable number of a mutant type—a type that we can introduce into the stock for the express purpose of recovering it by an apparent mutation process.

Dichete is a third chromosome dominant wing and bristle character and like Beaded a recessive lethal. In a certain experiment flies with the gene for Dichete in one of the third chromosomes and with a gene for the recessive eye color peach in the other were inbred for several generations. A lethal appeared by mutation in the peach-bearing chromosome very near the level of the Dichete gene in the opposite chromosome.

The order of these genes is shown in Fig. 4. This is then a

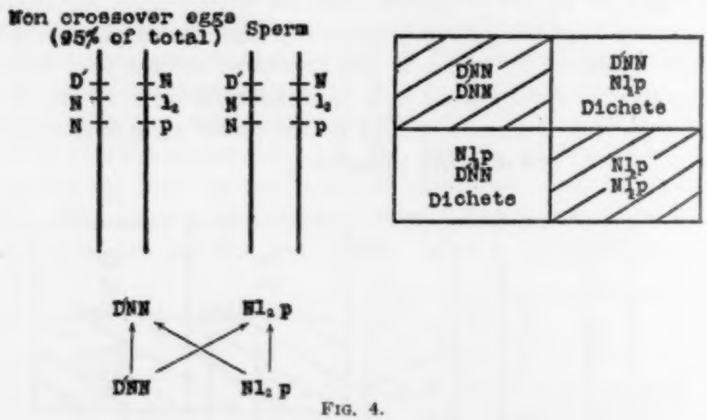

FIG. 4.

balanced lethal stock that throws only Dichete flies,[1] except for a small percentage of Dichete peach flies due to crossing-over. The result for the non-crossover classes is shown in the next figure, Fig. 5. Only two of the four classes come through: the two that die are the one pure for Dichete and the one pure for lethal. The surviving classes continue to produce the same kind of offspring since they are, like the parents, heterozygous for the two lethal factors. But the factors are not near enough together to prevent crossing-over. This occurs in about 5 per

[1] Very rarely a crossover not—Dichete fly will appear.

cent. of cases between the lethal and peach genes. The next diagram, Fig. 5, shows how when crossing-over takes place in

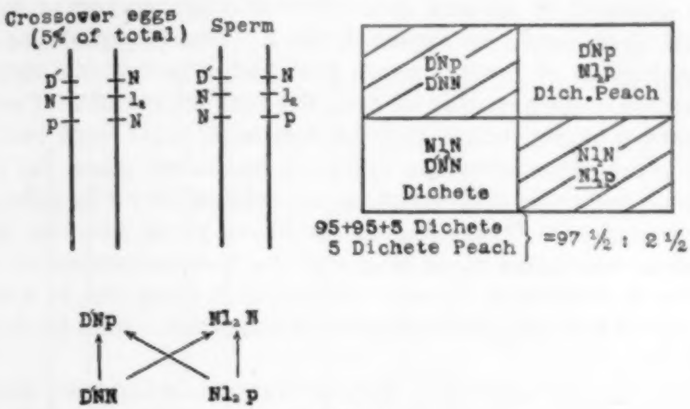

FIG. 5.

the female, there result (see squares) four classes of which two die (as before), and of the two that survive one is Dichete peach. Taking both non-crossover and crossover results together, the expectation is $95 + 95 + 5$ Dichete to 5 Dichete peach or $97\frac{1}{2}$ to $2\frac{1}{2}$. This stock then breeds true for Dichete without showing the gene it carries for peach eye color except in a small percentage of cases, and if the peach-eyed fly should be unable to establish itself in nature, like some of the *Œnothera* mutants, the stock would not be changed by it, but continue to throw off a few "mutants" with peach-colored eyes.

Now this process is not what is ordinarily meant by mutation, for we mean by the latter that a new type has suddenly arisen in the sense that some change has taken place in the germ plasm—a new gene has been formed. The process here described is one of recombination of genes shown by Mendelian hybrids, the only unusual feature that all the phenomena involved do not come to the surface because many classes are destroyed by lethals.

The results are interesting also in another way. It has been assumed by those who think that *O. Lamarckiana* is a hybrid that the mutant types are only the segregation products of the types or combinations that went in to produce the hybrid. But the *Drosophila* cases show that balanced lethal stocks may arise within stocks themselves by the appearance in them of lethal factors closely linked to other factors—new or old ones. When new genes arise in such lethal stocks the process may be

one of true mutation, but the revelation of the presence of the gene is hindered by the lethal factors, so that when the *character* appears, it appears in a much smaller number of individuals than would be expected for a "free" mutant due to recombination of mutant genes that had arisen in an earlier generation. As a matter of fact, the first appearance of even ordinary mutants, unless they be dominant, must come two or more generations after the mutation has taken place, for the evidence indicates that mutation appears in only one chromosome at a time.[2] In the case of sex-linked genes, however, any mutation that takes place in one of the X-chromosomes of the mother is revealed if the egg containing it gives rise to a son, because he has but one X-chromosome and that comes from his mother.

The delayed occurrence then of mutants in balanced stocks is not different from the delay in other stocks,—only when the recombinations occur in balanced lethal stocks they must have been preceded by crossing-over which diminishes the number of mutants that appears. The number of mutants that appears is determined by the distance of the genes for the character from the nearest lethal gene.

One of the most interesting features of the evening primrose arises when it is bred to certain other species or varieties. It gives rise to two kinds of offspring called Twin Hybrids, to one pair of which De Vries gives the names *læta* and *velutina*. Now it is a feature of balanced lethal stocks like Beaded that

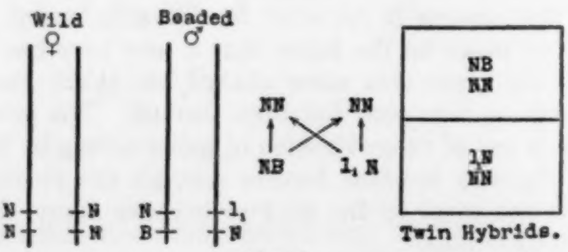

FIG. 6.

they repeat precisely this phenomenon. For instance, if a Beaded male is crossed to wild female, two kinds of offspring are produced, viz., Beaded and normal. A similar process would account for twin hybrids in *Œnothera* crosses. There is another peculiar phenomenon that has been described for

[2] If in self-fertilizing forms a mutation takes place far back in the germ plasm the new character might appear at once.

crosses in the evening primroses, viz., the occurrence in F_1 of four types. This phenomenon, too, can be imitated in *Drosophila* by crossing balanced lethal Dichete to balanced lethal Beaded (Fig. 7).

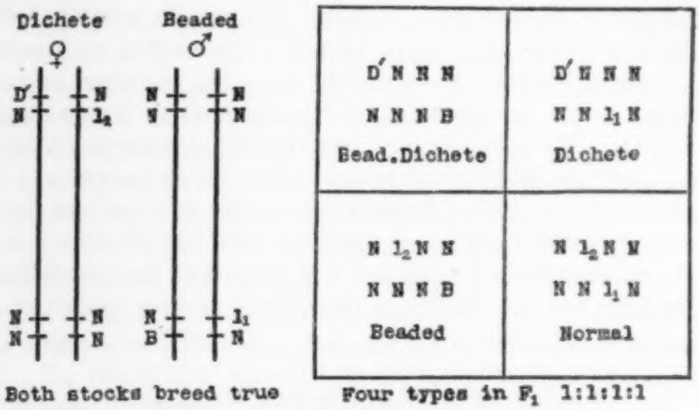

FIG. 7.

Other parallels might be cited, but these, I think, will suffice to indicate very strongly that the discovery of balanced lethal stocks may solve the outstanding difficulty of mutation and inheritance in *Œnothera* and bring it into line with other groups. There are, of course, other peculiarities of the evening primrose that such zygotic lethals will not explain; such, for instance, as the 15-chromosome type; and *O. gigas*. But these cases are already on the road to solution.

The occurrence of other lethals, called *gametic* lethals, that kill the germ cells—gametes—before they are ready for fertilization, has already been invoked by De Vries and others to explain the peculiarity of double reciprocal hybrids. As *Drosophila* has not shown any *gametic* lethals, we have no such parallel to this case, but confirmatory evidence has been found in other cases, as in *Matthiola* (Stock), and it is not likely that De Vries's hypothesis will be seriously questioned.

If this diagnosis is correct, the "mutation" of *Œnothera* is nearer solution than ever before. Much that has been obscure is clearing up. The so-called *mutation process* in *Œnothera* has turned out to be, I venture to think, largely a phenomenon of lethals—zygotic and gametic.

Whether the genes now present in the plant arose by incorporation of mutant types by hybridizing has no longer the same interest that it had before the discovery of the phe-

nomenon of balanced lethals, because the most characteristic "mutation" process of *Œnothera* is difficult to explain even if it arose through hybridization, unless the races that entered into its composition already contained balanced lethals. In which case it is the latter relation that gives the unique feature to the *Œnothera* mutation process, and not its possible hybrid combination. On the other hand, if the lethal and mutant genes arose directly in *Lamarckiana*, its peculiar mutation behavior would be due to their presence, quite irrespective of its history. In other words, it is in either case the balanced lethal condition that gives to this plant its extraordinary propensity to throw a considerable percentage of recurrent mutant types. Possibly I am too unfamiliar with the *Œnothera* work, or too optimistic, but I can not but rejoice at the possibility of accounting for the riddle of *Œnothera* on the theory of balanced lethal factors.

Nature of the Unit of Mutation

Undoubtedly the conception of the gene as a complex organic molecule or group of molecules located in the hereditary materials is the view most easily visualized when dealing with mutational "units," but however attractive and practical such a simple notion may be, we can not afford to accept it without careful analysis of the evidence supposedly in its favor. What is this evidence?

The segregation of the members of each pair of Mendelian genes clearly leads to the idea of independent units. It would be unprofitable to discuss whether these units are material particles or dynamic centers independent of material support. Standing on a chemical basis as physiology does to-day, we may without further discussion take for granted that the genes are some sort of chemical bodies.

The evidence that these bodies are carried by the chromosomes is also on a substantial footing. This evidence has been so fully discussed in recent books and articles that it need not be taken up here.

The assortment of the different pairs of Mendelian genes has been found to be conditioned by the phenomenon of linkage which is now reasonably explained by the assumption that linked genes are those carried by the same chromosome. This interpretation is gaining ground in all fields of genetics and in my opinion has been demonstrated to be true for the chromosomes of *Drosophila*.

The linear order of the genes in the chromosomes—each chromosome containing one linear order—is the only view so far suggested that will account for all the facts relating to linkage with its associated phenomena of crossing-over and of interference.

Beyond this point conclusions become more problematical. How much or how little of the chromosome thread corresponds to a gene can at present be deduced only from the genetic evidence. Some of the possible deductions that can be drawn from this evidence seem to be the following:

So long as a stock breeds true to a given standard, in the sense that its individuals fluctuate about the same mode, the stock bears evidence to the constancy of the genes. This conclusion rests on the assumption that the differences shown by the individuals of such "pure" stock are due to differences in the environment that each has encountered in the course of its life. To prove this view to be correct required the carefully controlled experiments that Johannssen carried out with Princess beans. In this case, through long inbreeding, which its natural self-fertility ensured, the stock had become homozygous for all of its contained factors. Hence individual size difference must have been environmental and this was shown to be the case, for when the large beans and the small beans that came from the same parent were sown, the group of individuals derived from the small beans showed exactly the same distribution as the group from the large beans.

Does this demonstration of the constancy of the gene mean that the gene itself is an absolute quantity? The mutationist has sometimes been reproached on the grounds that he deduces the constancy of the gene in defiance of the plain fact that all races of animals and plants are variable, and that this variability is indeed their chief peculiarity. The answer to this supposed reproach is two-fold: First, nobody claims that Johannssen's evidence demonstrates that the gene is absolutely fixed in the sense of being quantitatively invariable; and second that the expected results for the group of individuals studied would be the same whether the gene were absolute in a quantitative sense or whether its "constancy" were due to its variability about a critical modal quantity. This point has been so little discussed and so often misunderstood that it may be well to consider it for a moment.

Let us use the term, quantitatively fixed, in the sense in which a molecule is said to be fixed. Leaving aside the finer

distinctions that might be made on the grounds that some recent work has shown that even the same chemical element may exhibit differences in its atomic weight, it will not be disputed that modern chemistry goes forward on the assumption that the molecule is a fixed quantity. If the gene is a fixed quantity in exactly this sense, results of the kind that Johannssen has found are consistently explained. But there is no evidence that conclusively establishes this view. As an alternative view the gene may be looked upon as a certain amount of material that varies about a modal amount. The amount with which the individual starts might then be supposed to influence the characters of the individual in the plus or minus direction as determined by the starting point. On the other hand, even if individuals started with slightly different quantities, the fluctuations in the amount throughout the process of cell divisions that build up the embryo might be expected to neutralize the initial difference. In other words, the assumed quantitative fluctuations of the gene in the germ-plasm stream might be expected to recur also in the body cells of the individual and "compensate," so to speak, for any variable differences at the start. Before we can hope to make any further advances along these lines it may be necessary to know more about the chemical structures of the chromatin thread and the process involved when it splits lengthwise into two daughter threads. In the meantime it is permissible to use the expression "constancy of the gene" in either sense defined above.

In the course of Mendelian work in general and more especially in connection with the clean-cut cleavage phenomenon behind Mendelian segregation the question has come up as to whether the heterozygous members of the same pair of genes may not contaminate each other either during their long residence in the same cell or in the supposedly more intimate union during the brief conjugation of the chromosome threads at synapsis. We know too little of the relation of the chromatin materials at either of these periods for any *a priori* argument to carry the slighest weight. The decision must come from the genetic evidence itself. If such a phenomenon were of general occurrence it would of course entirely obscure the whole Mendelian idea of segregation. It has not been claimed by any one in a position to weigh the evidence that contamination is general. The appeal has been made only in a few cases in order to account for supposed departures from the Mendelian process of clean separation of the genes. In not one of

these cases, so far as I know, has the evidence been convincing, and in none of them has the alternative hypothesis of modifying factors been excluded. Until such evidence is brought forward it seems more probable that the generally admitted process of clean separation of the genes is characteristic of the segregation process. How this result may at times apparently be obscured will be described later when dealing with modifying factors and also with multiple allelomorphs.

The constancy of the gene may be made to appear in a somewhat ludicrous light when a commonly accepted view of mutant genes is brought into the present connection. The presence and absence hypothesis assumes that mutation is due to loss of a factor from the original germ plasm. Taken in a literal sense the absent factor is gone, and there can be no opening for a discussion of quantitative values or of contamination. This and many other difficulties are settled once for all by presence or absence. This might, indeed, be claimed as an advantage for the hypothesis. But on the other hand, the hypothesis has never had any direct evidence to support it. It was proposed as a formal way of expressing the fact that the normal allelomorph and its partner are constant and members of a pair that segregates. Any other formulation that expresses clearly this relation explains the data as well.

It is true that there was behind the idea a form of anthropomorphism that has made a wide appeal. Many mutant characters appear as a loss when considered from the viewpoint of the original character. The great majority of the familiar mutant characters are recessive, and most of them show the character less highly developed in a sense than the same character in the wild form. For instance, white flowers and albino animals appear clearly to be due to a loss of pigment. The paler colors of several mutant races, such as thirty mutant eye colors of the fruit fly, seem less well developed than the red eye color of the wild fly. If it is legitimate to argue from the degree of development of the character to the condition of that mutant gene that stands in causal relation to it, a plausible argument may be made out for presence and absence. There are, however, not only counter arguments that have as much or as little weight according to one's personal inclinations, but in the case of multiple allelomorphs there is evidence against this interpretation, and it is important to insist, that since it is here only that we have any really critical evidence, it is hardly fair to ignore it.

The arguments against the interpretation of absence are as

follows: *First,* it is entirely illegitimate to argue from the nature of the character to the nature of the change in the germ plasm that produces the character. Theoretically it must be conceded that any change in the germ plasm should be expected to produce some change in the character or characters of the individual, and if the wild type has been brought to a high stage of development almost any change might be expected to cause a falling away from the highest condition that has been attained. But "any change" need not be a loss in the germ plasm.

Second, in order to account for dominant mutant characters the adherents of "presence and absence" feel obliged to assume a loss of an inhibiting gene, because it is difficult for them to believe that an absence could dominate a presence. There is, however, no *a priori* reason why an absence in the germ plasm might not cause a dominance in the character, for the character is, after all, only the sum total of all of the influences in the germ plasm. The concession made here by the adherents of presence and absence is interesting, however, in so far as it shows how literally they take their absences.

Other *a priori* arguments might be brought forward, but the evidence from multiple allelomorphs is so convincing that it is not necessary to discuss the hypothesis in a purely formal way. In fact, if the hypothesis were understood only as a convenient way of formulating Mendelian results the discussion would resolve itself into one of personal preference, and have no further weight; but as will be pointed out later this interpretation has been used as an attack on the mutation theory itself, for losses do not appear to be the stuff that evolution is made of. Bateson has recently developed a kind of evolutionary scheme that attributes all change to loss, shifting the problem of the origin of the genes to a remote past instead of attempting to solve the problem. It is, however, not this theoretical possibility that I referred to above, but to attacks on the mutation theory on the grounds that the mutation process is different in kind from the changes that lead to the evolution of animals and plants. This point may be next considered.

Does Mutation furnish Evolution with its Materials?

There is a predisposition on the part of systematists, paleontologists, and a few other students of "wild" types to deny that mutants are identical with the variation from which evolution obtains its materials. The reasons for their objections might repay more careful and impartial analysis than they have yet received. The chief contention that evolution has been by

means of very small changes does not require further attention, since we now know that some of the genes that are typically Mendelian in behavior produce even smaller differences than those that distinguish wild varieties and paleontological gradations. Unless such small specific and paleontological differences can be studied by the exact methods familiar to students of heredity it is not possible by inspection for any one to make any statement in regard to their hereditary behavior as Mendelian units or as not such units. By way of illustrating how difficult it may be even when genetic material is available to detect the nature of a slight change, I need only recall the fact that some of the mutant differences depend on specific modifiers that act visibly only when the chief factor so-called is itself present. Another illustration is also to the point. Owing to the many-sided effects of single genic differences the *structural* effect of a gene may be only a by-product of other important and essential physiological effects that it brings about. Hence any deductions based on the visible changes in the structure may be entirely misleading.

It is important not to forget that any haphazard change in a highly organized piece of machinery is likely to injure the machine. There must be comparatively few alterations that would improve the adaptive relation of such a system. Furthermore, changes are more likely to succeed if they affect some detail than if they cause sudden and great alterations, for even an extreme alteration, in itself beneficial when considered alone, may be injurious unless the rest of the organism is in harmony with it. It is no doubt this last consideration that is uppermost in the minds of those who contend that evolution must take place by slight advances in directions that do not throw the organism out of harmony in the delicate adjustments already acquired. It is true that many mutant changes are extreme ones and hence will be rejected in general competition, or indifferent, and hence have small chance of getting a foothold. It is, however, unfair to extend this consideration and infer that no mutations will be advantageous. In fact, unless evolution is directed by mysterious Unknown Agents along adaptive lines, by Unknown-chemical-elements, *i. e.,* by some Bion, the chance that any random change will be disadvantageous is inevitable, regardless of whether variations are due to mutations or to some other sort of change. If past competition has raised living species to a high point of efficiency in the environment in which they maintain themselves, the expectation of improvement through any one random change must be very small.

Some at least of the differences of opinion between the mutationist and the systematist may be traced to the above sources. There are also other grounds of disagreement: (1) The fact, for instance, that most of the characters studied by mutationists appear to be deficiencies has prejudiced students of evolution against these characters as a class. (2) The fact that most of the mutant types as well as many of the domesticated animals and cultivated plants can survive only under the artificial conditions of man's care may appear to put them all out of court when comparisons are made with wild types. (3) The fact that many of the mutant characters of domesticated forms are recessive has been supposed to count against their consideration as factors in evolution.

These "facts" undoubtedly call for consideration. Let us attempt to give them their full value and see if they really invalidate the view of the mutationist who believes that the mutations that he meets with throw light on what kinds of variations contribute to evolution.

In answer to the first (1) objection, that many mutant types are deficient, *i. e.*, less complicated, it should be pointed out that the objection would hold only if all mutants were deficiencies. This is not the case, for some of them are actual additions or further developments of the original structures. No one would pretend to maintain that the majority of mutant changes have a survival value. But mutationists do think that mutant changes having a survival value arise in the same way as do others that have no such value; for, they can point to actual cases where such mutants have survived and replaced the original type, and they have found no evidence that supports the view that useful and useless characters arise in entirely different ways. The opponents of the mutation theory have occasionally tried to make it appear that mutationists believe that most of the deficient mutant types that they study represent, or might represent, possible stages in the evolutionary process. I do not know of a single advocate of such a view—it is palpably absurd.

The second objection, viz., that mutant types survive only under domestication, has really no bearing on the question unless it could be shown that all mutant characters are unfitted for survival. As a matter of fact, numerous cases are on record where mutant differences characterize wild races and species of animals and plants.

The third objection is more difficult to meet because the relation of dominance to recessiveness is always a relative matter,

and also largely a matter of definition. The following considerations have nevertheless a bearing on the supposed difficulty: (*a*) Dominant mutants, if they introduce an advantageous change, have a better chance of survival than recessive ones equally endowed, because the individual that carries the dominant gene has the immediate survival advantage that the character endows it with. (*b*) Since it appears that a large proportion of mutant types are recessive, the chance, that any wild type gene that occurs has arisen as a recessive mutation is increased. (*c*) After genes have been incorporated in the wild type there is no way of knowing whether they arose as a dominant or as a recessive mutation. That they may later be more likely to produce new genes recessive to them is not an argument that they themselves arose as dominants.

There is a further consideration to be noted in the above connection. It is not true that most dominants are superior to the wild type from which they arose. Several known dominant mutants are no better off than other recessive mutants, conversely some new recessive mutants have a higher survival value than some of the new dominants. It is questionable whether dominant mutants as a class are better endowed for survival than recessives.

In conclusion, then, it appears that the objection to recessives is based on the ground that they are mutants rather than that they are recessives.

There still remains a further highly theoretical consideration that may be briefly referred to in this connection. Why so many new mutations should be recessive is admittedly a problem for which we have no solution. It will not suffice to state that the wild type will probably be more stable if the mutant is a dominant, for, so far as we know, the stability of a gene has nothing to do with its dominance. There is evidence that the mutant gene is as stable, in the sense that it is no more likely to mutate again, as is the allelomorphic gene representing the wild type. Suppose, however, that the wild-type gene is a highly complex compound or molecule. It seems plausible to assume that disintegrative changes would be more likely to occur than changes that build it up into higher stages of complexity. Suppose, further, that degradation (loss of complexity) carries with it the likelihood that the character itself is less highly specialized, or developed, or conspicuous (any vague phrase will suffice), it may then appear reasonable that the more highly specialized end product will be the furthest reached

and hence dominate the product derived from any degraded stage.[3] Such considerations are highly speculative at the present stage of genetic work and we lack entirely evidence that can give them any special weight. For the present it is better, I think, to leave such difficulties in abeyance. It is, however, not improbable that we may gain some light on this question when we come to know more about the relations of mutant dominant genes to the wild type gene, from which they are derived. Already some important facts have come to light in the behavior of the gene for Bar eyes in *Drosophila*, as shown by Zeleny and May.

It should not pass unnoticed that the preceding discussion takes for granted, by implication at least, that new genes do not appear; in a word, that the most primitive organism had the same number of genes as have the more highly evolved animals and plants. Bateson has shown where the assumption that all new genes are losses of old ones leads. But the opposite point of view is tenable, viz., that new genes arise during evolution, and even that evolution is due to their appearance. How new genes could arise is unknown—whether by a splitting process within the chain of old ones, or by doubling of chromosomes, or duplication of parts of chromosomes, or out of some less specialized substratum in which the existing genes are embedded. If the mutations that we study are really only degradation products (losses if one prefers) of genes that have arisen in a different way during the evolutionary process, it might still be conceded that they are useful in recombination which may be one, even though it may not seem to be the most important, phenomenon of evolution.

It is true that practically all the genes we know anything about are transmitted according to Mendel's laws, and it is only genes so transmitted that are involved in heredity, except in the few cases of plastid transmission. If, then, it should be claimed that evolutionary genes arise in a different way from Mendelian genes, it must be granted that the former behave as partners to the latter in the same way as the latter behave as partners to each other when they meet, as in the case of mul-

[3] Bateson, arguing from character to gene, has suggested that the mosaic distribution of color, for example, is due to a fractionation of the gene. The speculation above has only a remote resemblance to this view. There need be no relation whatsoever between the nature of the change in the gene and the way in which its effects are distributed except that, as here suggested, degradation of the gene may weaken the extent to which some end stage or part of that end stage is realized. For dilution effects the two views are not so obviously different.

tiple allelomorphs. Such a relation can not, however, be used to establish the identity of the two suppositious classes of genes. We must search elsewhere for evidence bearing on this important question.

Mutant Species and Unit Characters

In his original definition of the Mutation Theory, De Vries regarded the change, however slight, as one that was far-reaching, producing an individual that was something new throughout. He compared the mutant types to the small species of Draba verna or to other polymorphic groups familiar to botanists. The Mendelian work led at first to a somewhat different conception of the change involved in a single mutation. The emphasis was laid on "unit characters," so-called. It was generally implied that a mutation in the germ plasm led to a change in some particular organ of the body, *i. e.*, its effects were localized, not general. During the seventeen years that have elapsed since De Vries's formulation it has become apparent that the more familiar we are with a given form the more changes we can generally recognize associated with a single mutation, although it is also true that in many cases some one organ often shows the effects more conspicuously, and this organ is chosen as a matter of convenience as the earmark of mutation. On the whole, the evidence has made it clear that De Vries was more nearly right in his diagnosis. The more extreme claim would be that a change in any gene in the germ plasm affects all parts of the resulting individual. The opposite claim would be that a change in the members of a pair of genes affects only a particular part of the body, thus identifying "unit changes" in the germ plasm with "unit characters" in the individual. The evidence that we now have shows that in most cases at least neither extreme statement corresponds with the facts, but that while the particular genes often produce their most marked effects on certain regions or organs of the body, yet it is no less important to recognize the widespread effects of mutant genes. Any attempt to identify the nature of the gene from the changes it produces in one organ can not safely ignore its other effects in other organs. If the products of a gene do not act on a particular organ in its final stage, but through a chain of reactions in the embryo, we should expect more than a single kind of effect.

If, as just stated, each gene may affect several parts of the body, it follows with some probability that the same part may

be affected by several genes. A similar conclusion is reached in another way. There are many mutants that show differences in the same organ, each difference dependent on a different gene. In the fruit fly, for instance, there are about 50 different eye colors, 15 body colors and many races with wings of different length, shape and breadth. It is probable that at least several, perhaps all, of the normal allelomorphs (genes) of the eye colors may also take part in the formation of the eye color in the sense that they all take part in building up the body, and the end result is modified according to the substratum that they have produced. Carried to an extreme the view might mean that every part of the body is influenced by the total of all the genes, which means, of course, the entire germ plasm. The conception is exactly the converse of the Roux-Weismann conception of the relation between the germ plasm and the end-product of its activity, which conceived each end result as the special product of one or a few particular genes. The statement sometimes made that the modern genetic conception of the gene is identical with that of Weismann is not even half true. What the two theories have in common is not peculiar to Weismann, viz., that the germ plasm is made up of discrete particles—a view held by Bonnet, Herbert Spencer, Darwin, Haeckel and several other naturalists—and what the two views do not have in common is the special relation between the gene and the character that Weismann, following Roux (who in turn goes back to Bonnet, not to trace the theory to the preformationists themselves), made one of the chief supports of his theory of development.

It is not necessary to advocate the extreme view mentioned above—that every part is influenced by the whole germ plasm. As yet our information is too meager to warrant such a wide generalization, yet speaking personally the view is more sympathetic to me than the one that limits the influence of each gene to a very few regions of the body. I incline more to the other side, because the embryological history of the individual shows that the differentiation of the organs is a gradual process through which successive stages are passed in building up the complicated end product. If each of the stages is under the influence of the hereditary material, any alteration at any stage in the building up might be expected to affect in some degree the end results.

This relation is somewhat similar to another relation, but the two should not be confused with each other A specific gene may be essential to the normal development of a certain organ,

which organ through an internal secretion may affect other parts of the body, or even the body "as a whole." If, for example, the development of the thyroid gland were known to be dependent on the presence of a certain kind of gene (amongst all of the others involved in its formation) a change in the postulated gene leading to the arrest in the development of the thyroid gland would, owing to the lack of a sufficient amount of some internal secretion of that gland, produce a malformed child with all of the various stigmata of the cretin. The conclusion that the gene ultimately produces its effect on the body by means of an internal secretion, here thyroidin, does not mean that the gene itself is thyroidin. It is conceivable that it may be, but such an assumption is not a necessary deduction from the evidence, and is not needed for the logical interpretation of the results. We hope of course some day to discover the nature of the materials that we call genes and the way in which they affect the developmental process, but in the meantime the distribution of the materials of the germ plasm during the ripening of the eggs and sperm is the center of present interest to students of Mendelian heredity. While I am aware that this statement may seem to take a too narrow view of the problems involved, separating as it does the mechanism of Mendelian heredity from the later physiological influences of the gene on embryonic development, it has proven in practise premature to base speculations as to the composition of the gene on the physiological processes that take place at some unknown stage in the development of the embryo even although these processes are admittedly due to the presence of a special gene.

THE APPLICATION OF ORGANIZED KNOWLEDGE TO NATIONAL WELFARE

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THE highest duty of every nation is to live up to its possibilities. If it performs this duty, its welfare is assured and it will command the respect of all other nations. The greatest problem before any nation is that of developing its resources to the utmost. The solution of this problem involves a thorough knowledge of all resources—natural, intellectual, manual and financial—and thorough knowledge of all means of making the most of them. Since our knowledge is far from complete, fundamental principles must be determined by research, and the application of those principles to special problems investigated. Finally, since productive life periods are relatively short, attention must be given the transmission of valuable accumulated knowledge by education.

Every military upheaval focuses attention on fundamental national problems. The lessons learned during the period of a war constitute its most valuable product. One of the great lessons of this war is the value of highly developed resources in inhibiting warfare and in determining its outcome. It behooves us therefore to give earnest consideration to the problem of living up to our possibilities. We have organized knowledge, judgment and experience sufficient to make a good start and the time appears ripe to consider ways and means of making more effective our efforts to further the interests of our country and of all sound portions of the world at large. This outline of some of the more general problems involved may serve to direct increased attention to such problems. Although the value of the application of organized knowledge by specialists to problems of general interest is a matter of the simplest common sense, we are only beginning to apply organized knowledge in an organized manner and the results to be anticipated from such an application are almost beyond conception.

Problems directly concerning the welfare of the nation fall chiefly into six groups: (1) Problems concerning the relation of this to other nations, (2) national problems, (3) problems con-

cerning relations between the nation and organizations within it, (4) problems relating to organizations, (5) those concerning the relation between organizations and individuals and (6) problems relating to individuals. More or less common to all groups are certain general classes of problems of such general interest as to be worth special treatment, namely, (7) education, (8) research and (9) the psychology of achievement.

1. *International Relations.*—Problems in international relations have to do with the relation between one nation and another of equal sovereignty and approximately equal strength, between one nation and other lesser nations, between a nation and its dependencies and with the rights of a nation to deal as it will with its own internal affairs.

The fundamental principle governing international relations is simple from a biological point of view. Those principles will in the end prevail which are backed by the greatest bulk and activity of resources; natural, intellectual, manual and financial; in other words, by the greatest sum of potential and kinetic energies. Mere intellect or money alone will not prevail, nor will natural resources or military strength. The creed of national selfishness goes down before the creed of altruism because it is inconsistent with true international democracy. This can recognize no special privilege among nations, since it is not in accord with the biological principle just stated. In these days of international information and activity, international public opinion will have its way, since it commands the bulk of effective resources. Hesitancy to sacrifice industries and individuals and intrigue by a minority may delay a settlement, but the final outcome is assured.

The right of one sovereign state to deal with another as it sees fit has never been explicitly conceded nor denied, since no direct means of enforcing regulations have existed. The problem of limitations is comparable with that of the right of one individual to treat another as he pleases. Common sense says that a policy of amity and equity is by far the most advantageous; common law holds that certain limitations may be exceeded only at the risk of certain penalties. A nation that oversteps the bounds of amity and equity in its dealings with its neighbors must just as surely pay the penalty, for human races the world over detest a bully and love fair play. In the interest of humanity, however, codes should be formulated and should be enforced by an effective international police in order that bullying and wars for aggrandizement should be put an end to for all time.

All political rights of the smaller sovereign states will undoubtedly be guaranteed by the economic majority of other nations at any time the issue is forced. Such nations are entitled to identically the same inalienable rights to exist, develop and manage their own affairs that are possessed by the strongest nations. On the other hand, the non-political rights of such lesser nations are properly proportional to the massed resources of each.

The relations between a nation and its dependencies must be based on the same principle if there is to be development without revolution. There must be such free interchange of resources as will benefit both colony and mother country. A nation whose policy is one of fair play leaning toward altruism will always be successful with her colonies, while a policy of selfishness and condescension will ruin the best of colonies. Finally, as a colony grows there must be continued readjustment of political rights to keep pace with the increasing relative bulk of intellectual and economic resources in the colony.

The basic principle of world democracy politically is the complete abolition of special privileges. The logical application of this principle to international relations means complete autonomy, self-determination, government by and with the consent of the governed. The practical problems in this field relate to the establishment of such limitations to these rights as may be necessary to secure the ultimate greatest good of the world at large.

2. *National Problems.*—The various classes of national problems center about the single one of securing the maximum development and utilization of resources. Progress requires first of all stability and stability depends primarily upon efficiency of administration. Comprehensive surveys of resources —natural, intellectual, manual and financial—are required as the first step in their development, utilization and conservation. Corps of trained experts must say what can be done and how it can best be done. The actual work of development, conservation and utilization falls chiefly upon individuals and organizations, but it is a governmental function to supervise at all times and regulate when necessary. National authority should be asserted in proportion to national responsibility, that is, to the extent to which the interests of the people as a whole are affected.

Administrative problems relate chiefly to resources and are dealt with through various departments and bureaus. It goes

without saying that each class of problems should be cared for by a specialist in that class of work and that the leading specialists of the country should be at the service of the nation. In order to secure an adequate supply of such experts, it may be best to reorganize various departments and bureaus to perform somewhat more of the functions of graduate schools than at present. This would attract more and better men to the national service and secure for the nation and for the industries more high-grade experts in the application of organized knowledge to practical problems. Along with the elimination of partisan politics and other kinds of special privilege, it would be in the interest of administrative efficiency to put in effect a national system of advancement—the student becoming a specialist, the specialist with ability and experience becoming an expert and the expert with broad and sure judgment advancing to the higher administrative positions. This is the "Business Method" and is beyond question the best method of securing efficient administration.

A democracy may be either the best and strongest or the worst and weakest form of government, according to the extent to which it adopts business methods, putting its ablest experts in control at the top and having all important problems solved by specialists. Such a democracy will have a considerable advantage over even the best form of autocracy, since in the latter the governing class is not chosen from so wide a selection.

3. *The Nation and Internal Organizations.*—National stability requires that national authority be supreme over every internal organization, whatever its nature; political, industrial, religious, protective or otherwise. And stability is the first requisite of a national organization. The principle is that the interests of the people as a whole (the nation) must be rated higher than the interests of any component part, be it an individual or a powerful state or industrial organization. Biologically, this all-important principle is so simple as to be absurd. Unless parts of our bodies, for example, worked harmoniously together for the common good, we could not long exist.

The practical problems in this field relate chiefly to the proper limitations to be placed upon organizations to secure the greatest possible good to the nation. The Sherman Law aimed to secure the national welfare against the encroachments of powerful organizations seeking only their own selfish aggrandizement. Its enforcement has resulted in serious inter-

ference with normal growth. Such growth should be encouraged, but firmly directed toward the national welfare.

Other more sinister organizations seek not only their own welfare and aggrandizement above that of all other people in the nation, but acknowledge a higher allegiance to an alien head than to the nation. This anomaly is of course a serious menace to national stability and could not long exist except under the cloak of secrecy and evasion. There is but one solution for this problem—elimination of such kind or kinds as are applied to cancerous growths.

Labor organizations, on the other hand, are entirely loyal as a rule, but their aims at first sight appear crude and selfish and evidence little regard for the interests of those not within the organization. Every strike, however, is more than a mere demand for higher wages or for greater power through the closed shop. It is a back fire against the equally selfish aggrandizement of capital. Due to its entrenched position, capital has always been prone to claim special privilege and the lion's share of the profits accruing from the cooperation between laborers, capitalists and engineering experts. It will be difficult to solve the problem of fair play in this case, since it involves the equitable distribution of earnings where no general rules are perhaps possible. Such equity depends largely upon lateral conditions, and these vary widely in special cases. The government is confronted with this problem (1) in an advisory capacity in dealings between industrial organizations and labor and (2) wherever it employs bodies of labor.

4. *Relations between Organizations.*—Problems concerning the relation of one organization to others are relatively few and simple. In equity each one, small or large, must be secured the right to grow and develop its resources without other limitations than those demanded by the general welfare. Combination and secession are to be carefully regulated. Combinations to secure greater efficiency and economy are to be encouraged and fostered while side combinations for the purpose of securing exclusive rights are not to be tolerated. Wide latitude may safely be given any organization in the management of exclusively internal affairs. No special privileges can be granted one organization or class of organizations that are denied others.

5. *Relations within Organizations.*—Problems concerning relations between organizations and subordinate organizations and individuals are similar in character to those concerning

relations between the nation and internal organizations—strictly internal affairs are not to be interfered with from outside. Industrial organizations present problems of difficulty. They are essentially triumvirate in nature, consisting of (1) plant, tools and materials representing capital, (2) technical information and skill and (3) operating labor. In the larger older organizations the three are quite distinct; a group of bankers supply the capital, hired experts do designing, testing of raw materials and product and make sales while more or less skilled labor keeps up routine production. The equitable divisions of earnings and losses is a difficult problem. When capital assumes responsibility for losses or contributes valuable ideas it is obviously entitled to a larger share than when it does neither. When technical experts shall have become as strongly entrenched as both capital and labor now are, the working out of the principles of equity may be brought to an issue.

6. *Relations between Individuals.*—The principles governing relations between individuals are already fairly well covered by the ordinary civil and criminal codes, worked in accordance with common sense and equity over long periods of time. Some of the more difficult and but partly solved problems involve the basis for compensation for service and equity in cases in which psychic forces are a factor. Special privilege is to be everywhere denied, that is, equality of rights and privileges must be everywhere secured and guarded.

Nowhere else is the premium on superior strength, skill or activity greater than with individuals. Let the winnings be limited to the winners. Inherited wealth, position, or influence should be regarded as an asset to the nation and a probable destructive agent for the inheritor. Individual talent is by far the greatest asset of the nation and its development and utilization the greatest single problem. That great group of problems dealing with the attainment of the maximum knowledge and skill by the individual relates to the education of the expert. Another important group of problems relates to securing a maximum of achievement; and still another to the increase and application of organized knowledge.

7. *Development of the Expert.*—In a really efficient democracy all important problems will be in the hands of experts for solution. Since men of ability come about equally from all classes, provision must be made to train and select individuals from all classes alike. In a broad sense, every one who applies special knowledge to special problems is an engineer, be he electrician, physician, bridge builder, skilled agriculturist, banker

or teacher. Some specialists, such as the physician and the farmer, require many volumes of special information and years of experience in its application. Other specialists require chiefly breadth and generality of knowledge, picking up their special training in a few months. In each profession preparation starts with the most general academic information, proceeds to "make believe" real problems and ends with problems involving full responsibility.

Interest in the general problem centers largely on (1) equality of opportunity, (2) efficient general instruction and training—mental, moral and physical, (3) age of choice of specialty, (4) freedom to transfer from one line to another, (5) efficient semi-technical education, (6) technical instruction and training through practical work and research, (7) state and national coordination in aims, methods and standards and (8) government boards of specialists to investigate and advise as to efficiency in methods and enhanced quantity and quality of output.

Our present mobile, ill-defined policies in education have been well adapted to our period of rapid national development, but the time is at hand for systematized improvement under the guidance of trained experts. The preliminary development has been well done—our educational system, such as it is, is "close to the ground" and already approximates roughly to our requirements. We need chiefly unity and refinement of methods. The rigid elimination of educational weeds and all similar glaring defects long tolerated should come first of all. Our racial stocks of raw material are excellent—able and eager to learn. It must be admitted, however, that our methods are slack and our typical product a "slacker" until caught in the whirl of real life. Our greatest problem with our own sons is to put "sand" into them, to fire them to achievement. Lax school discipline and low standards do not help; in fact, the results of lax school methods frequently persist through life.

Our engineering schools and other methods of developing experts are as a rule excellent in aims, methods and results. Perhaps the greatest need is for increased attention to thorough knowledge of fundamental principles. It should be continually emphasized that the chief factor in the standing of any engineer or professional man is his command of fundamental principles. We are a practical nation and are too prone to pick up knowledge by experience and let it go at that, paying too little attention to the results already achieved by others. The mere quack is the extreme type of deficiency in knowledge of fundamental principles. The problem of the complete elimination of

quackism involves modification of curricula in some instances, but is chiefly dependent upon our instructors and leaders in each line.

Finally, some sort of supervision might well be exercised over the process of education that continues through middle and later life. All real experts continue to acquire further knowledge of fundamentals and additional skill through experience as long as they live. The problem is to make such knowledge more available and to increase opportunities for professional intercourse for the interchange of ideas and experiences.

8. *The Increase of Organized Knowledge.*—Man's inquiring mind is forever prying into things and frequently dislodges an idea worth exhibiting and preserving. Some of these either alone or built into a structure of previously discovered ideas prove highly useful or instructive or entertaining or otherwise contributory to his well-being. To achieve certain desired results, he searches the general storehouse for an idea or principle applicable to the purpose. That failing, he digs in the unknown to find one. Research uncovers new ideas, engineering applies to special problems general principles already known. Research shades off into engineering on the one hand and into creative art on the other. It ranges from the very general and fundamental to the special and practical. Without it we should have had none of the sciences and none of the products of the sciences.

The bulk of the research work is done either in (1) educational institutions, (2) the administrative departments of the government or in (3) special research laboratories supported by various industries. Some fields of research involving expensive equipment and from which little or no financial return is to be expected have been provided for by private endowment.

Since our higher educational institutions are our chief conservers and disseminators of organized knowledge, it is but natural that they should lead in the development and extension of that knowledge. However, the plant is designed primarily for teaching and is but ill adapted to research. Neither students nor instructors have more than scraps of time to put on research, while effective research requires steady, continuous application. The biggest problem in university research is to remedy these conditions.

Since the university instructor's time is devoted chiefly to teaching fundamental facts and principles and the student's chiefly to acquiring them, the research undertaken by both is

naturally adapted to these purposes. This is doubtless as it should be. Our chief ground for criticism is (1) that the instructor is too crowded with teaching to do enough research work to found a real school for specialists and (2) the student either does not take his work seriously enough or give it time enough to get results of any great value as a rule. Under the circumstances, it is rather surprising—a credit to native ability—that so many pieces of really good work are turned out.

Industrial research laboratories have been started in great numbers in recent years in response to insistent demand for more precise knowledge and a clearer understanding of the fundamental principles applicable to specific problems. The public does not realize the desperate plight of a plant that has run into some obscure works trouble, stopping production. As in cases of illness, diagnoses quickly but surely made by experts are indicated and treatment is prescribed, but by physicists, chemists and engineers as physicians. The original industrial laboratories were staffed by scientists retained largely to look after works troubles where they occurred. Then there is raw material to be tested, specifications to be written, product to be tested, new products and processes to be nursed along into the works.

A full-fledged research division of a large industrial concern may properly consist of two wings, one devoted to fundamental research, the other to engineering research covering routine testing and the simple works troubles. The former covers the field between pure science and special works troubles and may be expected to yield a considerable harvest of scientific papers as well as patents and technical reports. With work continued day after day on full time and means always at hand for obtaining needed equipment or assistance, it represents research under its most favorable conditions. Stakes are high so that there is abundant incentive to earnest effort, in fact pressure is likely to run too high for best results.

The chief problems connected with industrial research laboratories are of a minor nature; securing a sufficient number of good physicists and chemists—men thoroughly grounded in fundamentals—having a high degree of originality, together with good judgment, (2) making it easier for research men to come and go, thus putting all research laboratories more on the basis of graduate schools and (3) improving the interrelations between universities and industrial laboratories.

National research has to do with the solution of problems concerning general welfare. Like industrial research, it ranges

in character from pure science to statistics and pure engineering—the application of known principles to specific problems. It covers public health, transportation, communication, finance, education, labor, patents, standards, weather and statistics as well as the conservation, utilization and development of natural resources in minerals, agriculture, fisheries and forests. Much of the research is in the nature of special problems and nearly all of it can be most efficiently accomplished by highly trained experts. Since as a rule these experts are not to be had ready trained, the government must select and train its own from among persons of sufficient general academic training.

Government technical work is carried on by the greatest single body of scientifically trained experts in the country and is on the whole well planned and carried out. There is a large percentage loss (20 to 30 per cent. annually) of the best men in some bureaus—practically the same as in institutions of higher education—hence government research bodies constitute in a sense a great graduate technical school. This condition is to the advantage of the country at large, but it would undoubtedly be for the best interests of all if a higher percentage of the best men were retained in the service. Conditions indicate that (1) higher salaries should be paid and a better system of promotion put in force to retain in the services more high-grade men. (2) The work should be more highly organized and centralized to promote team work and cooperation. Possibly a sort of university organization with a few lectures by experts and many seminars and conferences would be advantageous in attracting good men to the service and giving a wide selection from which to draw. Obviously political appointments should be limited to clerical and unskilled labor and should be limited even in those classes.

9. *Incentives to Achievement.*—However great our knowledge or skill, we accomplish nothing unless fired to achievement by powerful incentives. As a rule we produce hardly ten per cent. of the results of which we are capable, due partly to lack of opportunity, but mostly to lack of incentive. We are a nation of slackers. We fail to live up even to our opportunities by at least seventy per cent. Obviously then the problem of incentives is one of the most vital in the problem of the welfare of the nation.

Men of great achievement are invariably those who supply or create their own incentives. They are typified by the hen which, of her own effort, was unable to fly over a fence, but by worrying a dog into chasing her, was able to mount the fence

with ease. The incentive of the hen roost was inadequate, but that of self-preservation was ample for the task to be accomplished. Men of achievement are not content merely to earn a living or even to live up to a certain standard, but are constantly spurred to greater endeavors, to attacking ever more difficult problems, to win over ever more powerful rivals. A fatuous content with existing conditions and previous accomplishments is as intolerable as a shirt of fire.

The psychology of achievement presents many complex problems not easily disposed of. Both temperament and education are involved. Incentives to activity are many and varied, some of the most powerful arising in ideas and impulses coming apparently from nowhere. The choice of activities leading to greater or lesser achievement is always with us and that choice frequently depends upon factors almost fortuitous. It is hoped that these problems may receive the most serious consideration of psychologists as an issue in national welfare.

In conclusion then it may be stated that the proper field for the application of organized knowledge is to secure and enhance the national welfare through increasing the strength, the skill and the activities of the nation, the organization and of the individual. The nation requires organized knowledge for administration, for safeguarding the public welfare and for directing the best development, utilization and conservation of national resources—natural, intellectual, manual and financial. Organizations require it for the attainment of the purposes for which they are organized. Individuals require it to assist them in living up to their possibilities. Although the advantages of its application are matters of the simplest common sense, we are but beginning to apply organized knowledge in an organized manner. The results to be anticipated from such a general and systematic application are almost beyond conception.

THE WORK OF MUSEUMS IN WAR TIME—II

By HARLAN I. SMITH
GEOLOGICAL SURVEY, OTTAWA, CANADA

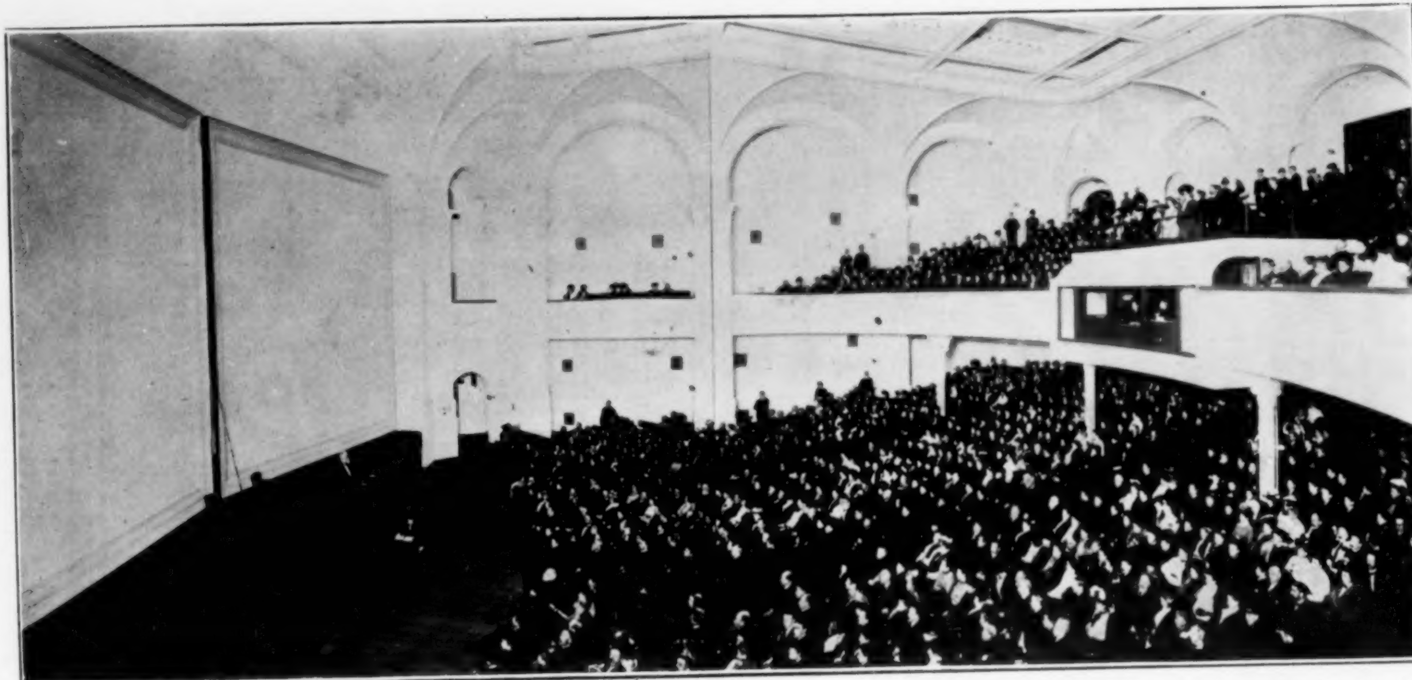
VISITORS

IN peace times most visitors come for recreation. The report to the British Government Committee on the Health of Munition Workers states that observations for a year on the output of workers employed in making fuses showed that a reduction of working hours was associated with an increase of production both relative and absolute. Generally, the cumulative effects of fatigue neutralize and overpower efficiency produced by practise. In the absence of rest and recreation the fatigued worker has no opportunity for complete recuperation

TAKING MOVING PICTURES OF BIRDS ON AN EXPEDITION OF THE GEOLOGICAL SURVEY, CANADA.

and his output, though more uniform, remains permanently at a lower level than that shown by a worker who has had rest and recreation.

Some museums are devoted entirely to recreation, but never-



Museums like Universities have Lecture Halls and Vast Audiences use them. In the American Museum of Natural History. They may be well used in war time.

theless all the exhibits are instructive. Recreation now is especially necessary to relieve as much as possible the unnatural strain on both civilians and soldiers. Properly administered museums not only furnish this healthful distraction but at the same time can also instruct and inspire.

Museum Lectures

Museums like universities have lecture halls and vast audiences use them in ordinary times. In war time these and their illustrative apparatus for projecting lantern pictures and moving pictures may be well used not only for war-time publicity but also for giving recreation or instruction. The instructive lectures may be given to the forces being trained and to convalescent returned soldiers who are unable to carry on their former occupations and who need a new means of livelihood. The recreative lectures may be given to ease convalescent suffering. The moving pictures, of such cheering subjects foreign to war and its frightfulness as birds, photographed on expeditions, would serve well for this purpose. They would reach men who came to realize while lying wounded how sweet life and nature are when compared with the sordid rush for mere money.

Museum Photography

Thousands of negatives, prints, maps and lantern slides are made by the Photographic Division in the Museum of the Geological Survey, Canada. The lantern slides are used in the lecture hall and are loaned throughout Canada. This work is also done in many other museums and is part of the education needed to make a people efficient in the arts of warfare and in those necessary behind the lines as well as always needed in the arts of peace. The museum workers who make and use these materials, often taking photographs under difficult situations resembling some war conditions, are fitted to assist in developing new war-time photographic necessities such as are used by the flying corps in making photographic maps, detecting camouflage, etc., and that are absolutely necessary for the protection of an army as well as the destruction of its adversary. These workers are also better qualified than the average photographers to become teachers of such photographic work to the fighting forces.

Museum Visitors Future Soldiers

Classes of high-school children who in peace times marched to the lecture halls of the great museums grew up during the

Thousands of Negatives, Prints, Maps and Lantern Slides are made by the Photographic Division of the Geological Survey Museum, Canada. The lantern slides are used in the lecture hall and are loaned throughout Canada.

Classes of School Children in Line of March to the Lecture Hall of the American Museum of Natural History.

continuation of the world war and contributed many men and officers to all branches of the fighting forces. Over seven thousand school children came to hear one lecture. This shows that the work of teaching school children in the regular subjects which are of use in war time must continue with increased efficiency during war so that suitably trained material may always be available. No one ever knows how long a war may

Over 7,000 Children came to Hear One Lecture in the American Museum of Natural History.

last. Even exhibits of objects connected with the war, such as guns and shells, may be used in a series to attract children to exhibits instructing them in regular studies such as history and physics, which will always be needed by both the citizens and soldiers of a country at war.

Temporary and Loan Exhibits

Museums loan space for horticultural and other temporary exhibits. These are placed sometimes for one or two days around permanent exhibits. In war time some museums loan space for war-time exhibits. For instance, the American Museum has had special war-time exhibits of food and health in war and peace. A popular handbook was issued for this exhibit for sale at the news stands. Both were especially prepared for

EVEN MUSEUM GROUNDS ARE AVAILABLE FOR SOCIAL USE. Folk dances are held by the children on the lawn of the American Museum of Natural History. In war time this ground is used for drilling.

the use of soldiers. All the museums of the country might well loan space for the exhibition of loan exhibits from the Food Controller. In June, 1917, Red Cross Week was held in the Museum at Newark, N. J., and a complete set of Red Cross supplies, conforming in every respect to the latest specifications of the American Red Cross, was exhibited. It included hospital linen and supplies, surgical dressings, operating-room supplies,

MUSEUMS LOAN SPACE FOR HORTICULTURAL AND OTHER TEMPORARY EXHIBITS IN PEACE TIME. These are placed for one or two days around permanent museum exhibits in the American Museum of Natural History. In war time this museum provided space for war-time exhibits.

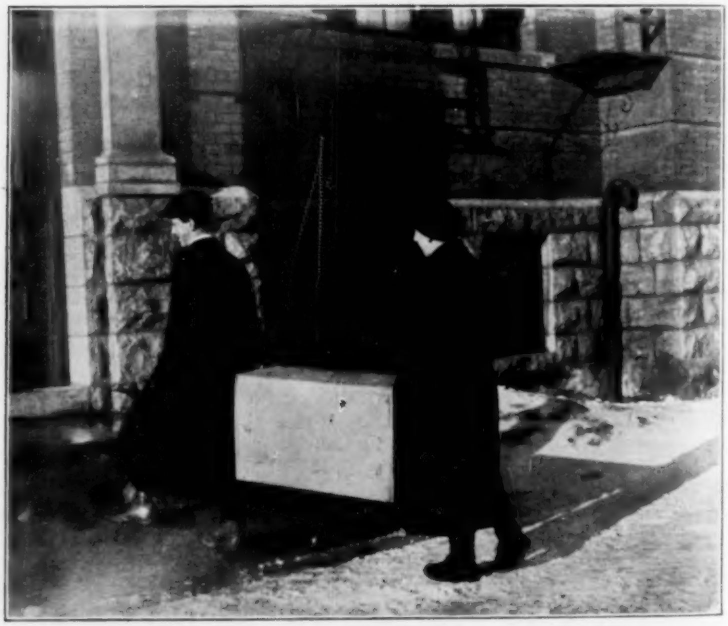
and linen, patients' clothing and such supplies as the Red Cross furnishes to the army and navy. A similar temporary exhibit including models and pictures was made in the U. S. National Museum.[3]

The windows and the glass of the cases in the Provincial Museum at Halifax were broken by the terrific explosion of the munition ship that blew up in the harbor. A water pipe burst and snow stormed into the museum, so in this emergency museum work was stopped and the cases were covered with boards and used as tables for Red Cross and other relief supplies.

Museums have aided in the food-conservation campaign of the United States National Emergency Food Garden Commis-

[3] Cf. U. S. N. M. Rep. 1916, p. 121.

EXHIBITS ARE PUT IN TRAVELLING CASES TO BE SENT FROM SCHOOL TO SCHOOL IN OTTAWA.

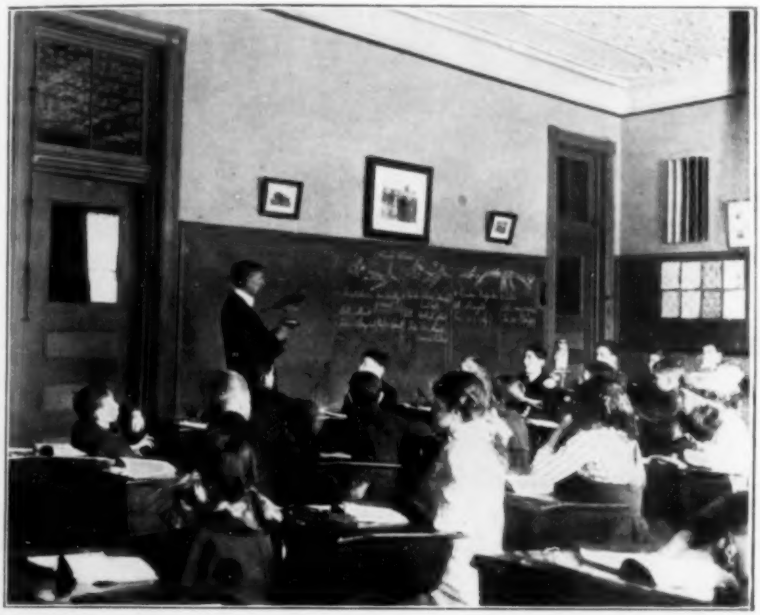


SCHOOL BOYS CARRY THE MUSEUM TRAVELLING EXHIBITS FROM ONE SCHOOL TO THE NEXT IN OTTAWA.

sion by distributing to visitors quantities of manuals attractively illustrated and printed. This material and other literature were placed with the "help yourself" cards where visitors to the museums readily see and take them.

Museum Grounds

Even museum grounds are available for war service as well as social service. Folk dances were held in peace times by



Travelling Exhibits from the Museum of the Geological Survey are used in the Schools of Ottawa.

the children on the lawn of the American Museum of Natural History, but, after the United States entered the war, the grounds were used for drilling. The Brooklyn Museum grounds were planted by the museum workers and considerable food was raised by them.

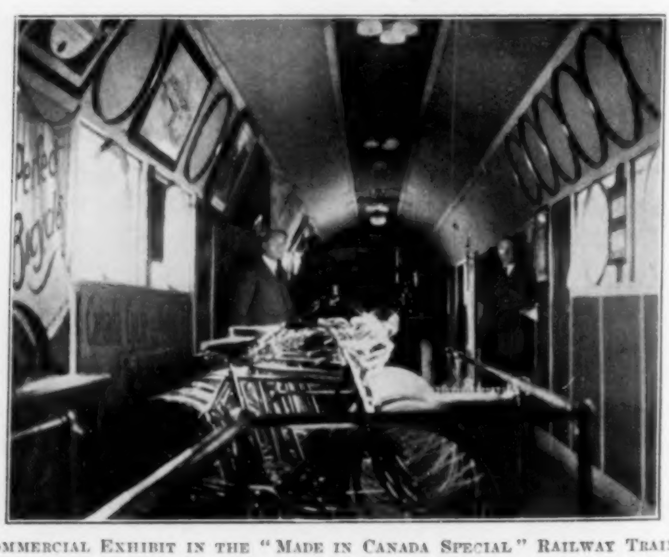
Travelling Museums

Exhibits are put up in travelling cases to be sent from school to school in Ottawa, St. Louis, Chicago, New York, and other places. School boys carry the museum travelling exhibits from one school to the next in Ottawa, while in St. Louis, New York, and Chicago, this system of museum extension has grown

A Commercial Museum on Wheels. The "Made in Canada Special."

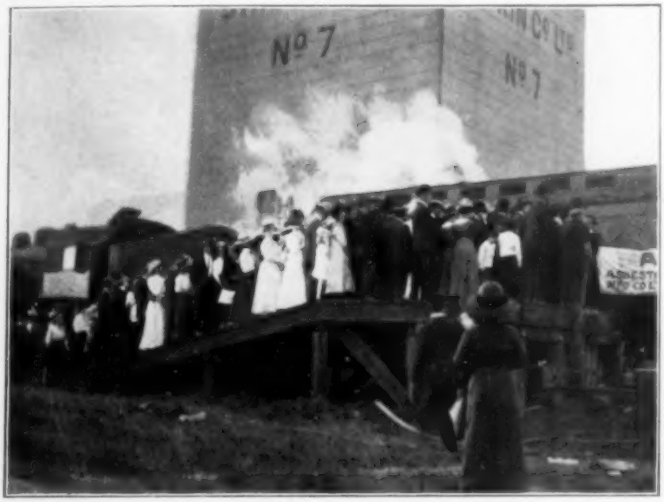
so in recent years that a special auto delivery van is used for the purpose.

The St. Louis Public School Museum makes as many as thirty deliveries of such exhibits in a single day. It delivered 66,810 separately boxed groups of material to the schools during the school year 1916–1917, and has called into service an additional delivery truck. Every public-school teacher of St. Louis is welcomed to select from the new catalogue and order the



Commercial Exhibit in the "Made in Canada Special" Railway Train.

collections she can best use to illustrate the various lessons planned for the week. The delivery trucks serve every school once a week, collecting the material previously delivered and depositing the material ordered for the current week. The entire annual expense to the Board of Education of all this museum work, including overhead expenses, salaries, delivery service, and additions to the collections, averages about 14 cents per pupil served. This method serves the country in



THE CROWD VISITING THE COMMERCIAL MUSEUM IN THE "MADE IN CANADA SPECIAL" RAILWAY TRAIN.

war time as does other educational endeavor, and may be applied to distributing special war-time instruction to schools, the public and the fighting forces.

A commercial museum on wheels, the "Made in Canada Special," carrying commercial exhibits on a railway train across Canada in peaceful years, was visited by crowds. The same means provides opportunity to spread useful war-time knowledge regarding conservation of food and fuel, the speeding up of necessary industries, the making of munitions, political propaganda as in the exhibition of captured guns, and the training of fighters. In the United States a Food Control exhibit has been installed in a railroad car.

MUSEUM EXTENSION

For years minerals have been given to Canadian schools by the Geological Survey, Canada. A covered tray containing

an elementary series is sent to the elementary schools, but cabinets containing five drawers to higher schools. Exhibits of things relating to war can be handled in the same way.

FOR YEARS MINERALS HAVE BEEN GIVEN TO CANADIAN SCHOOLS BY THE GEOLOGICAL SURVEY. A covered tray containing an elementary series is sent to the elementary schools; cabinets, containing five drawers, to higher schools.

COOPERATIVE LABELLING

Encyclopedic species labels were prepared as the text of the Handbook of the Rocky Mountains Park Museum by the Dominion Government and have already been used by eighteen different museums, the Rocky Mountains Park Zoo, and for several other educational purposes. Lantern slides have been made to illustrate some of them and these labels can consequently also be used as lecture notes. They need only to be shuffled when it is required to rearrange a lecture. The same method may be employed by the museums in supplying information needed by a nation at war.

RESTAURANTS

In large cities it is sometimes desirable to provide a restaurant in a museum so that students or other visitors may not have to go out. In the American Museum of Natural History, the restaurant is modelled after the ancient Mexican ruin of

ENCYCLOPEDIC SPECIES LABEL IN THE ZOO OF THE ROCKY MOUNTAINS PARK prepared as the text of the Handbook of the Rocky Mountains Park Museum by the Dominion Government, and already used by seventeen other museums and for several other educational purposes.

RESTAURANT IN THE AMERICAN MUSEUM OF NATURAL HISTORY. This is modelled after the ancient Mexican ruin of Mitla.

Mitla and, therefore, is an exhibit as well as a restaurant. In war time such restaurants should be made available to soldiers, sailors, and others engaged in activities of defense.

Conclusion

If the museum fraternity does not rise to the occasion and at least adjust itself to meet war needs and help the general progress of the world other agencies will take over what should be the most important part of museum activities. For instance, the Canadian department of Trade and Commerce opened a museum in January because of the need of such a museum in war time. Those in charge were not recruited from among museum men. The children's museums, which are at present apparently the chief hot beds of new museum ideas, are being made such by persons not formerly connected with museums. It was two boys who were trained in the Children's Museum in Brooklyn who sent and received the first wireless telephone message from Paris to Hawaii.

Now, when the young and active men from the small towns and the country districts of the whole world are passing through the great centers of culture such as London, New York and Paris, or are visiting them on leave of absence, is the very time when museums should be most active in entertaining, instructing, or offsetting the vicious experiences of the war. The cream of New Zealand, Australia, India, Canada, and many allied nations, gathers in London. What better time than now for the museums to offer these men attraction, recreation and instruction, and an inspiration to carry home to the individual corners of the world the seeds of the world's best fruits? Museum work, instead of being curtailed, should certainly be directed towards doing in war time its part both in fighting the war and in making up for the evils and deprivations caused by it.

THE ALSACE-LORRAINE QUESTION

By C. C. ECKHARDT, Ph.D.

ASSISTANT PROFESSOR OF HISTORY IN THE UNIVERSITY OF COLORADO

WHEN by the Treaty of Frankfurt of May 10, 1871, France was forced to cede Alsace and Lorraine to Germany there was created one of the most difficult and most permanent problems of internationtal relations. This question has remained one of the most active sources of international friction. It lies at the basis of the Triple Alliance, and of the counter alliances, the Dual Alliance between France and Russia, and the Triple Entente. It has been the cause of crushing competitive armaments. It was the cause of constant ill-feeling on the part of France toward Germany, and led to frequent friction between the two countries. In spite of Germany's having affirmed all along that the Alsace-Lorraine question was closed by the Treaty of Frankfurt, it has ever been on her mind. This is a question that concerns not only France and Germany, but it is of moment to every civilized nation.

From Cæsar to Bismarck. Alsace-Lorraine before 1871

France and Germany both have historic claims to these provinces; it is well therefore to consider the history of them previous to 1871. The earliest record of these lands dates from the time of Julius Cæsar, when they formed a part of Gaul. When the Germans invaded the Roman Empire in the fourth and fifth centuries they overran and conquered Alsace and Lorraine. Until 870 these lands were controlled by the Merovingian and Carolingian Franks. When the Empire of Charles the Great was finally divided by the Treaty of Mersen in 870, Alsace and Lorraine became a part of the German Kingdom. To this time these two provinces had had a common history; but now they were divided and until 1871 had a separate history. Lorraine became a duchy with an independent existence in Germany, and Alsace became a duchy attached to Suabia. Both regions were German-speaking.

In 1552 France, for the aid she rendered to the German Protestants against Charles V., was given as fiefs of the German Empire the three bishoprics of Metz, Toul and Verdun; and by 1648 at the close of the Thirty Years' War France was given

these three bishoprics in full sovereignty; they ceased to be a part of Germany. They were geographically a part of the

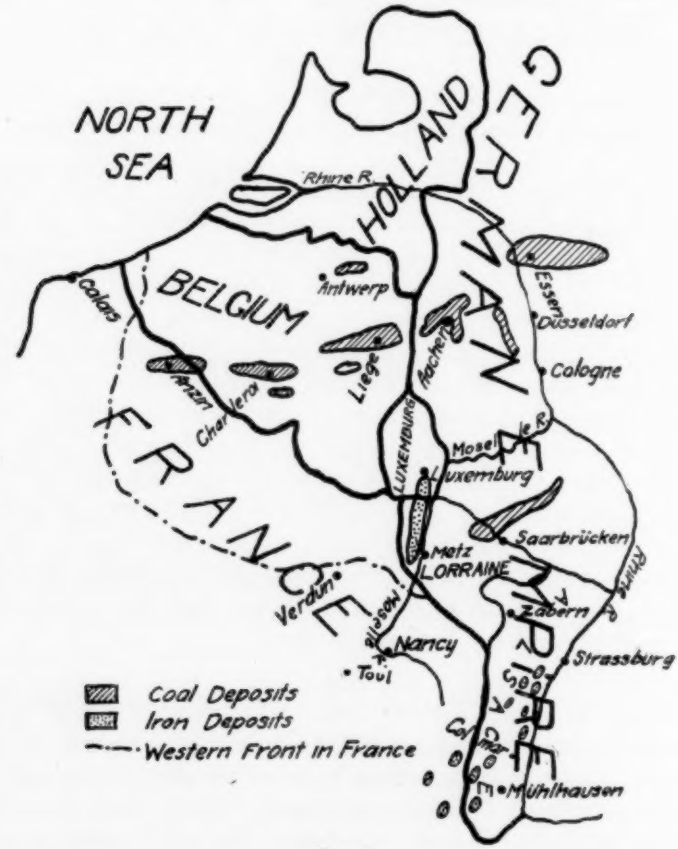


FIG. 1.

Duchy of Lorraine, but were independent of it, and were now a part of France. In 1648 France was also given Alsace as a reward for her services in the Thirty Years' War. Some added territories, Colmar and Strassburg, were secured by the French "courts of reunion," and in 1697 by the Treaty of Ryswick French possession of these was confirmed. Lorraine was in 1737 transferred to Stanislaus Lesczinska when he had lost his kingdom of Poland. He was father-in-law of Louis XV., and in 1766, upon the death of Stanislaus, the Duchy of Lorraine came into the possession of France. So by 1648 and 1766 Alsace and Lorraine, which had been separated from France since the ninth century, once more became a part of France.

Whatever attempts France made to assimilate these German-speaking people previous to the French Revolution were not

very successful. It was the French Revolution that aroused in the Alsace-Lorrainers a French sentiment. The democratic and liberal phases of the Revolution appealed to them; the republican principles fascinated them, and many Alsace-Lorrainers fought in the French wars in the armies of the Republic and Napoleon. It is regarded as significant that the "Marseillaise" was first rendered by Rouget de Lisle in 1792 at a dinner given by the French mayor of Strassburg.

Ever since 1815 the Alsace-Lorrainers have been largely French. In 1871 they were handed over to the German Empire much against their will, and when the French National Assembly ceded these provinces to the victorious enemy, the deputies from Alsace-Lorraine protested against this cruel separation from the mother country, and they were expressing the feelings of the greater part of the people of the ceded territories. When, in 1874, the fifteen deputies from Alsace-Lorraine took their seats in the Imperial Reichstag in Berlin, they also protested against the annexation of their lands by Germany. It is also interesting to observe that in 1871 the two great socialist leaders of Germany, Bebel and Liebknecht, father of Carl Liebknecht, protested against the annexation, and were imprisoned for their boldness.

Why Germany annexed Alsace-Lorraine

Germany annexed these lands for three reasons: (1) For linguistic and historic reasons. The Germans claimed that these provinces had been taken from Germany in the seventeenth and eighteenth centuries, and now these brothers were to be brought back into the fold and allowed to become Germans again. In the literature of Germany's political aspirations long before 1871 there were references and allusions to the need of regaining these lost provinces.

(2) For strategic reasons. Von Moltke persuaded Bismarck that these provinces were necessary for Germany's defense against France. The Vosges Mountains would be a far more satisfactory frontier from the military standpoint than the Rhine. Ever since then the Germans have claimed that the Vosges Mountains are the natural boundary between France and Germany.

(3) For economic reasons. Alsace-Lorraine contains much coal, iron and other minerals. But the German desire for these deposits was by no means as great in 1871 as it has become since that time.

Of all the reasons the military reason for annexation was

the most potent. Germany needed Alsace-Lorraine for purposes of defense, and the people of the annexed provinces were to be regarded as conquered dependents; they were to be kept in subjection at all costs.

The Émigrés and Immigrants

When Germany signed the Treaty of Frankfurt she agreed to allow all inhabitants of Alsace-Lorraine that wished to emigrate to do so by October 1, 1872. By that date 60,000 had left the country, all going to France or the French colony of Algeria. 100,000 others were not allowed to go because they had not departed by the prescribed date. But emigration has continued all along, from 5,000 to 12,000 leaving annually, and one French authority states that fully half a million people emigrated from the provinces between 1871 and 1910. Many of the people who emigrated did so because they did not wish their sons to enlist in the German army and later kill their relatives and friends in France. The 100,000 that were not allowed to emigrate in 1872 claimed the rights of foreigners, namely freedom from military service. But the German government refused to grant this concession, and this led to much emigration. Ambitious Alsace-Lorrainers wishing to pursue a military career will go to France, for in the German army they would have very little chance of promotion. In 1914 there were only three Alsatian officers in the German army, while there were thirty generals of Alsatian stock in the French army. In 1900–1913 over 22,000 boys fled from Alsace-Lorraine to enlist in the Foreign Legion of the French army.[1]

To take the place of the Alsace-Lorrainers that went to France Germany sent many colonists or immigrants into the conquered provinces. They were people in all the walks of life, and in 1914 out of 1,800,000 inhabitants, 400,000 were immigrants from various parts of Germany. They did the very things that would make them unpopular with the native inhabitants; they boasted of Germany's greatness, emphasized German superiority and tenaciously adhered to all their German characteristics, which increased the difficulty of reconciling the two peoples.

Government of Alsace-Lorraine Since 1871

When Germany had acquired Alsace-Lorraine it was thought best not to annex the provinces to any one of the German states, for then some of the German states would have felt that they

[1] Gibbons, "New Map of Europe," 16.

had fought in the Franco-Prussian War so that Prussia, or Baden or Württemberg could gather in the spoils. Bismarck felt that it would be the wise thing to make Alsace-Lorraine an imperial land—"Reichsland"—directly under the control of the Empire. That would make all the states equally responsible for the annexation and for keeping the spoils of war.

Previous to 1911 Alsace-Lorraine was not a member of the German Federation. For forty years it was a mere dependency, an imperial territory. Administrative affairs were conducted by the Emperor, the Chancellor and the Bundesrath. There was a representative of the Emperor, the governor-general, situated at Strassburg. In 1874 a territorial committee or "Landesausschuss" was created; its members were elected by the city councils of the four largest cities. At first the committee could merely give advice concerning local laws and taxation. By 1877 it could enact laws concerning local affairs; but these laws had to have the sanction of the Bundesrath, in which Alsace-Lorraine had no representation until 1911. Not all laws were made this way. Some were enacted by the Reichstag, the Bundesrath and the Emperor in the same way that all imperial laws were enacted. Moreover, the Emperor and Bundesrath could issue ordinances having the force of law; the governor-general was responsible only to the Emperor; he was virtually a dictator. Alsace-Lorraine was wholly ruled by outsiders. From 1879 to 1887 an effort was made to establish a mild rule for the conquered lands, but then this policy gave way to a rule of harshness, which merely intensified the prevailing dislike for Prussia.

In 1873 Alsace and Lorraine were allowed to send fifteen members to the Reichstag; but here they could exercise little influence, since that body is of little consequence, the real ruler of Germany being the Bundesrath, in which Alsace-Lorraine was not represented. From the beginning there has been a growing party that demanded local autonomy. As a result of the agitation by this party the imperial government in 1911 granted Alsace-Lorraine a constitution. Alsace-Lorriane could now send three delegates to the Bundesrath; but these were to be appointed by the governor-general, an instrument of the Prussian King. This merely meant that the strength of Prussia would be increased by three votes in the Bundesrath, and therefore it was provided that whenever Prussia by means of these three votes has a majority these votes were not to count. Plainly this kind of an arrangement would not satisfy the demands of those that wished Alsace-Lorraine to be represented on an equality with the other states of Germany.

This bill of 1911 also provided for changes in the local government of Alsace-Lorraine. Instead of the "Landesausschuss" there was to be a bicameral legislature of 36 and 60 members. Half of the 36 members of the upper chamber were to be appointed by the Emperor, the remainder were to be office-holders and representatives of chambers of commerce and other professional and business institutions. The lower chamber of 60 was to be elected by manhood suffrage by secret ballot. But this constitution has not satisfied the people. The Emperor can still refuse to sanction the laws of the local legislature, and the Alsace-Lorrainers have no power in selecting the three members of the Bundesrath. The Alsace-Lorrainers before 1914 wished to have local autonomy, their own sovereign or their own republic, and unqualified representation in the Bundesrath of the Empire.

The Language Question

It is difficult to secure adequate information concerning linguistic conditions in Alsace-Lorraine; statistics and opinions differ. The French maintain that the language of the lost provinces is still French. The Germans officially state that the language is preponderantly German, and what French is spoken is largely *patois*. However, one is safe in saying that on the whole Alsace is more German than Lorraine. Even in Alsace the large cities, Mühlhausen, Colmar and Strassburg, are French. The city of Metz in Lorraine is more French than any place in the two provinces, though in a standard German encyclopædia it is stated that only forty per cent. of the population of Metz speak French.[2] In this same work[3] is a map indicating the linguistic dividing line between the French- and German-speaking regions. This represents as French-speaking fully two fifths of Lorraine, and only small indentations on the French border of Alsace are indicated as French. Whatever the official statistics, the facts are that Alsace-Lorraine is not German from the German standpoint. French is still widely spoken; many newspapers are printed with both French and German on the same page; in the shops one is waited on with equal courtesy when speaking French or German. Although the street signs are in German, many of the people always refer to them in French. French plays are presented as often as the law allows, once in two weeks. The German government permits no new French business signs to be put up over the

[2] Meyer, Konversationslexikon, 6th edit., Vol. 5, p. 726.
[3] *Ibid.*, pp. 726–7.

stores. Therefore, old French signs, no matter how old and dilapidated, are still kept over the shops. If the owners tried to repaint the signs that would be equivalent to a new sign and would therefore need to be in German. If you ask an Alsatian whether Alsace is still French, he will answer: "It is not German yet."

THE TREATMENT THAT HURTS

On the whole the Germans have done little to conciliate and placate the people of Alsace-Lorraine. They have regarded these provinces as conquered lands and have treated the people in the very ways that would be designed to intensify the existing spirit of protest and opposition. The regulations are all of the petty and annoying kind. For asking an orchestra to play the "Marseillaise," or whistling it, the people are expelled or punished. When French veterans of 1870–1871 get together and talk over old times their meetings are dispersed and their guns taken from them on the ground that the guns are being carried without the veterans having secured licenses. Those Alsace-Lorrainers that left the country at the time of its cession may visit it only three weeks in the year. If they neglect to secure the required police certificates they must leave at once. Those that come back on business trips may see their clients only at the railway station; they may not enter the town. Parents are not allowed to send their children to foreign schools without governmental sanction, and this is granted sparingly. If the children are sent without governmental sanction the parents are liable to fine and imprisonment. In this way it is hoped to prevent the children from learning French, but this regulation seems to heighten the desire to acquire the language.

Only certain French newspapers are allowed to be brought into the country—those that have agreed to omit all reference to Alsace-Lorraine. But people living on the border of France drive over into France, buy the prohibited papers and the women of the party secrete them in specially contrived pockets in their petticoats. The Germans have levied a high tariff on many French goods entering Alsace-Lorraine. Young men leaving Alsace-Lorraine to avoid German military service may never return until they are forty-five. If detected they must pay a heavy fine. This means that unless the parents of such young men have ample means for travel into France they may not ever see their sons again. Even if able to travel, they must get the consent of the German government before they are allowed to leave. French conscripts from Alsace-Lorraine are sent as far as possible from home. If they get sick or die their

relatives can seldom reach them. During the fall maneuvers the people of Alsace-Lorraine must lodge and cook for as many soldiers as the government requires. At various times the manufacturers and merchants of Alsace have been carefully watched by informers to detect any pro-French leanings. When detected they are made to feel the full displeasure of the government. At Grafenstaden, near Strassburg, there is a great locomotive works that had for a long time supplied the railroads of the vicinity with locomotives. One of the directors of the company was a French enthusiast who made no attempt to conceal his sympathies. Suddenly the company was notified that unless it discharged that man it would secure no more orders from the government, and the company had to yield.

All of these circumstances explain why the Prussians are hated. They make it possible to understand the following incident. At Colmar a school teacher was describing vividly the cruelties of Alexander the Great when dealing with the inhabitants of a captured city in Asia Minor. A little girl in the class exclaimed, to the mortification of the teacher: "Surely he was a Prussian!"

One of the most striking outrages of German rule in Alsace-Lorraine was the Zabern or Saverne affair in 1913. At the barrack town of Zabern in Alsace a twenty-year-old lieutenant did various irritating things while in charge of his men. He made uncomplimentary remarks to his men about the Alsatians, he showed open contempt for the civilians. When the populace heard about these things they stoned his house and made annoying remarks to him when on the street. One thing led to another until finally a crowd was dispersed by the young lieutenant and his men, and he himself struck a lame shoemaker with his sword, inflicting an ugly wound on the forehead. Instead of being adequately punished the lieutenant was given the minimum sentence, forty days in jail. The German government did nothing to show that the military had been in the wrong; the protests in the Reichstag were unheeded. The whole affair indicated that the Prussian military government was absolutely dominant, that the civil population in all Germany had no rights as against the military, and it indicated especially that there was not the least inclination on the part of the imperial government to show a conciliating attitude toward the Alsatians. Whatever the German government had succeeded in achieving in the way of placating the conquered provinces was undone in a few weeks by the Zabern affair.

Educational and Industrial Development

However, not all of Germany's acts have been of the brutal, domineering nature. She has done much to promote the material, educational and religious condition of the people. Alsace-Lorraine has become a very important industrial center of the Empire; the iron and coal mines are the richest in the Empire, as will be shown later; the population has increased by 300,000 in spite of the emigration of several hundred thousand. Canals have been constructed; a splendid system of railways has been created; sanitation of the most modern type has been established. A splendid school system has been introduced; when these provinces fell into German hands education was not compulsory and was largely in the control of the Catholic Church. Now the same high type of schools prevails as will be found elsewhere in Germany.[4] Many of these benefits would have accrued to these provinces if they had remained in the possession of France, for in industry, transportation, sanitation, commerce and education France has also made much progress since 1871. But undoubtedly the greatest advantage that Alsace-Lorraine derives from her connection with Germany is of an economic nature, and the economic aspects of the question will be considered below.

The Various Views as to a Settlement. The German View

The Pan-Germanists maintain that Germany conquered these lands and was given them by the Treaty of Frankfurt. France has no rights in these provinces. The people of these territories have only the rights that Germany sees fit to give them. Whatever happens in Alsace-Lorraine is no concern of France. By international law the rights and interests of France ceased in 1871 by the Treaty of Frankfurt. The Germans declare that for years France had tried to suppress the German language and customs in these territories, and it is now the right and duty of the Empire to wean the Alsace-Lorrainers away from French culture and instil German culture once more. Napoleon III. began the Franco-Prussian war in order to gain the Rhine provinces of Germany for France. The Pan-Germanists say that Alsace-Lorraine was taken to prevent a repetition of such an attempt of France. Germany must keep her western boundary as it is. Military necessity demands it.

This is the view that is held by most Germans. To advocate other measures would be about as unpopular as it would

[4] Sir Harry H. Johnston, "Germany and Alsace-Lorraine," *Nineteenth Century and After*, 75: 40–41.

be for Americans to advocate our giving up Porto Rico, the Philippines or the Canal Zone; however, Maximilian Harden, the courageous editor of *Die Zukunft*, and some others, favor the granting of full autonomy, with certain rights in choosing a monarch.

The French View

Officially the French have never given up the hope of reconquering the lost provinces. Every year since 1871 a formal ceremony has occurred in which a wreath is placed on the Strassburg Monument in the Place de la Concorde in Paris, and the statue of Strassburg is constantly kept veiled in black to remind the French of the country's bereavement. However, among the second generation especially, this ceremony has had less meaning than for the older generation. After the Franco-Prussian War Bismarck did his utmost to divert the French from thoughts of revenge. By 1881 he had succeeded in directing France into the field of colonial expansion. France added Tunis and other African lands to her colonial possessions. She took a new interest in strengthening her political and commercial power in her dependencies in India, Indo-China, Madagascar and elsewhere. She became, next to Great Britain, the greatest colonial power in the world. Under these circumstances French ardor for reconquering Alsace-Lorraine was, in a measure, allowed to cool off. But the interference of Germany in Morocco in 1905 in the Tangier affair indicated to the French that Germany had broken the tacit agreement of Bismarck. If Germany were going to interfere in French colonial enterprises, that automatically opened the Alsace-Lorraine question again. The French newspapers have all along done their share toward keeping up an agitation for the recovery of Alsace-Lorraine, and they have done all they could to kindle a feeling for France in the hearts of the Alsace-Lorrainers. But there seems to be no evidence that there was a hearty response. Let me quote some typical statements:

> The writer, who had good opportunities of getting acquainted with the "Imperial Land" and its people in the decade preceding the European war, must share the opinion of those observers who were not able to find much real enthusiasm for France there. That there was much sentimental sympathy for the brilliant nation to the westward, particularly among the wealthier families, cannot be denied. But so far as could be judged, there were not many Alsatians or Lorrainers who would have liked to be French again.
>
> Forty-odd years of separation has not availed to make the inhabitants of the provinces Germans, but they have thoroughly unmade them Frenchmen.[5]

[5] R. H. Fife, "The German Empire between two Wars (1916)," 230–231.

Before the outbreak of the war in 1914 the Alsace-Lorrainers wished autonomy under German rule. After the outbreak of the war many Alsatians have claimed that they have always wished annexation to France. But Mr. Gibbons states:

> This is not true. It would be a lamentable distortion of fact if any such record were to get into a serious history of the period in which we live.[6]

The Alsace-Lorrainers' View

Whatever the attitude of the Alsace-Lorrainers since the outbreak of the war, they hoped for nothing better than autonomy under German rule before 1914. They wished to be as autonomous in directing their local affairs as Bavaria, Baden and Saxony. They are not Germans, neither are they French, they are Alsace-Lorrainers. In a splendid article written before the war, David Starr Jordan summed up the situation thus:

> The present attitude of Alsace is concisely summed up in these three lines of current doggerel:
>
> "Français ne peux,
> Prussien ne veux,
> Alsacien suis."[7]

The Alsace-Lorrainers value the prosperity that has come to them through being ruled by Germany. If they had been allowed to vote on their remaining with Germany with autonomy or returning as departments to France, they would have voted for the former. But this does not mean that they have any sympathy for imperial aggrandizement as advocated by the Pan-Germanists. They consider themselves as Alsace-Lorrainers, and wish to be left alone. Their slogan is: "Alsace-Lorraine for the Alsace-Lorrainers."

These are the views of the three parties concerned. It has often been suggested by outsiders during the last three years that the settlement of the question should be left to the vote of the Alsace-Lorrainers. It may be that now, instead of voting for autonomy under Germany, they would vote for annexation to France. But this method of solving the question would satisfy neither France nor Germany. France distrusts Germany; she would manipulate the election. Moreover, there would be no provision for the suffrage of those that emigrated, and they are vitally concerned too. If allowed to vote they would turn the election in favor of annexation to France. The Germans

[6] "New Map of Europe" (1914), p. 5.

[7] "Alsace-Lorraine: a Study of Conquest," *Atlantic Monthly*, 113 (1914); 282–287.

would never be willing under the present circumstances to submit the question to a plebiscite. If applied here it would also be applied with justice to Schleswig and Posen. Moreover, the importance of Alsace-Lorraine industrially makes the matter one for settlement by other means. This is a question of national honor to both Germany and France; hence neither would be willing to submit it to a vote of the people.

The Economic Bearings

While Alsace-Lorraine was annexed partially for economic reasons, to-day the Germans desire to keep it for economic reasons of much greater potency than those of 1871. In 1871 it was known that Alsace-Lorraine had coal and iron. But the iron ore was of the kind called *minette,* which contains two per cent. phosphorus; this amount of phosphorus was too large to make it feasible to use the ore. However, in 1878 two Englishmen, Thomas and Gilchrist, invented a modification of the Bessemer process that removed phosphorus from the ore and also produced a slag containing the phosphorus extracted from the ore. This invention benefited Germany greatly. She could now use her hitherto useless iron deposits and use the slag as a fertilizer to enrich the soil at home, and she also exported large quantities of this slag. Germany became a great industrial country. She was particularly well favored by nature. In the Rhine country at Saarbrücken and Essen are rich coal fields, and these are close to the iron mines of Lorraine and Luxemburg. These iron mines are the second largest in the world, those in Minnesota, Wisconsin and Michigan alone being richer. The region between the Moselle and Rhine rivers is the only one in Europe that has both coal and iron close together. In all other cases it is necessary to haul one or the other long distances in order to smelt iron. Owing partly to these circumstances Germany has outdistanced England in the iron industry. In 1914 Germany stood second to the United States in steel output. Before 1871 Germany produced only half a million tons of steel, in 1911 she produced fifteen million tons, and about three fourths of the ore came from Lorraine and Luxemburg. This ore could easily be transported to Saarbrücken and Westphalia, and this fortunate combination of natural resources has produced such new industrial towns as Essen, Elberfeld and Düsseldorf.

In the first weeks of the war Germany took Luxemburg, Belgium and northern France. In Luxemburg she secured the remainder of that rich deposit in northern Lorraine. Belgium

and France have rich coal beds. In the Anzin region in northern France nearly three fourths of the French coal supply was produced previous to 1914. So Germany struck a heavy blow at French industry, and greatly strengthened her own resources for carrying on the war. It is plainly evident that if Germany be allowed to retain any of these conquests—Belgium, northern France, Luxemburg—her industrial and military supremacy would be greatly enhanced. She would not only dominate Europe, but also be able to endanger the position of the United States as the foremost steel producer of the world. It is therefore interesting to us Americans to observe that in the allied countries there is an insistence on Germany's giving up not only Belgium, northern France, and Luxemburg, but Alsace-Lorraine as well, in order that she may be so crippled industrially that she may not be able to continue her militaristic policies.

The Alsace-Lorraine question is to-day not merely a question of patriotism and strategic frontier. There is also the economic aspect that seems more important than the other two. Germany could better afford to yield Alsace-Lorraine from the linguistic and strategic standpoints than from the industrial and commercial standpoint.

It is plainly evident that to-day the Alsace-Lorraine problem is still unsolved. Three things stand out clearly: (1) The annexation of 1871 was unjust from the standpoint of the French nation and the Alsace-Lorrainers themselves. (2) If there is any justice in the annexation Germany has failed to convince the Alsace-Lorrainers of it, and has been unable to instil in them a feeling of loyalty and devotion to the Empire. The Alsace-Lorraine question is still a menace to Germany and to the rest of the world. (3) The economic phases of the question have merely complicated it. No matter how the question is settled there will be an injured party, either France or Germany, and probably the people of Alsace-Lorraine too. If Germany loses Alsace-Lorraine her industrial life will be crippled, and she will have a desire for revenge as France has had. This is an exceedingly knotty problem and will be solved only when there is a new spirit actuating nations in their international intercourse. If we can at the close of this war establish a workable system of international government, supported by a new spirit of international friendship and cooperation, the difficulties of the Alsace-Lorraine question will vanish along with many other questions of international friction that promise to disturb the peace of the world for ages to come.

BEEKEEPING AND THE WAR

By Dr. E. F. PHILLIPS

BUREAU OF ENTOMOLOGY

IN former times, beekeeping was a more important branch of agriculture than at present, but the development of trade with the tropics made possible the bringing in of cane sugar and honey production decreased in relative importance. It is far from being a lost art, however, for in normal years the United States produces about 250,000,000 pounds of honey and the amount is increasing steadily. That this much honey is available is a matter of surprise to most people, for many American families never include honey in their menus, and the only honey which many people eat is that which is concealed in cakes for the purpose of keeping them moist for a considerable time. The small amount produced is sufficient to provide a little over two pounds annually for each person, equivalent only to three per cent. of the sugar consumed in years of sugar plenty.

The amount of sugar on every hand in the form of nectar is so great as to stagger the imagination, but some estimate is possible. In a year of prosperity a colony of bees consumes for its own uses a great amount of honey, this amount having been variously calculated as from 200 to 600 pounds. The lower estimates doubtless obtain only for weak colonies, and the average amount may be placed conservatively at 400 pounds. While the bees are gathering this for their own use they are perhaps providing 50 pounds additional which the beekeeper may take, making the estimated total gathering of the colony 450 pounds. An apiary of 100 colonies will frequently, on this estimate, gather 22½ tons of honey in a season. This comes from a territory included within a radius of about two miles. While the beekeeper harvests only a meager 2½ tons, the total of 22½ tons has been produced by the nectar-producing plants in that area. This, it should be remembered, is sugar produced in a region where most persons would not recognize the presence of any sugar production. To assure the sceptical reader, it may be stated that there are often

apiaries where the average yield of surplus honey is over 200 pounds, this being the honey which the beekeeper takes for his own use. Yields of 600 pounds to the colony have even been recorded for unusual circumstances.

It is conservative to state that there is every year produced in nectar-producing flowers in the United States more sugar than is consumed by the American people. Obviously, since the bees consume so much, only a small part of this vast wealth can be conserved for human food. The honeybee, so often compelled to serve as an example of industry, does not appear as an efficient collector of human food, when its necessary consumption is recalled. However, any agency for the conservation of this vast sugar supply must be one which is ever on the alert, since the nectar is so soon lost after it is produced. No agency other than the honeybee has as yet been found which will save any of it for man.

Speculation, such as the above, may be subject to criticism, but an unanswerable argument lies in the records of commercial beekeepers. There are thousands of places where commercial apiaries are now established and as the industry expands beekeepers do not experience difficulty in locating additional apiaries all around their home locations. Within the last decade commercial beekeeping has shown a rapid development and yet it would be extremely difficult to find a place where there are so many colonies as materially to reduce the crop. In a few localities beekeeping has been especially developed and if the same progress had been made throughout equally favorable localities, the honey crop would be more than twice what it is to-day. Any one familiar with the conditions surrounding the industry must realize that the crop may be increased ten times without increasing the cost of production per pound.

Why has this sugar supply been so generally wasted? It is not easy to answer this question, but the answer probably lies in the nature of the beekeeping industry. Beekeeping is applied animal behavior. The honeybee is still, after years of human care, in no sense a domestic animal. Its reactions to external stimuli are, so far as known, what they were when cave-men first robbed them of their honey. Man has by selection in breeding changed the color of the abdominal bands in certain strains of Italian bees and he has selected those which are less inclined to sting, but no progress has been made in any fundamental change of bee nature. The successful beekeeper

is therefore necessarily a student of bee behavior, so that he may adapt the activities of the bee colony to his ends. He has learned that by providing the proper conditions he may not only increase the gathering power of the bees but he may have a larger part of the honey stored in such shape that he may take it. He has also learned that by attention he may reduce swarming, thus preventing the bees from wasting their energies in making more colonies when he desires honey rather than more bees. But bee behavior is rather a complex subject into which to initiate the average citizen. It is a subject of impelling interest if properly presented but it is so far from the type of study necessary for other branches of agriculture that an insufficient number of people have taken up the work with sufficient thoroughness.

Beekeeping differs from other branches of agriculture in that little land is needed in its pursuit and only in rare cases is it necessary to use land which is useful for other agricultural purposes. The production of honey does not deplete the soil. An important consideration is that the commercial beekeeper is exceedingly busy at just the time when the man engaged in general farming can not find time to give to bees. Beekeeping does not mix well with general farming and must usually be combined either with work other than general farming or with some other specialized branch of agriculture. To a large degree this takes the beekeeper out of the country and it is a fact that most commercial beekeepers live in towns and suburbs. The small ámount of land needed, combined with the small necessary expenditure for apparatus makes it safe to say that in proportion to the investiment there is no other branch of agriculture which yields so great a return. However, it must not be assumed that beekeeping is a rapid and easy road to wealth. The returns which the beekeeper receives are directly proportional to the labor and especially to the intelligent care which he invests.

The literature on beekeeping has not been of a type which would induce people to take up the work as a commercial industry. The trouble is not that there are too few beekeepers, for the United States boasts about 800,000, but is rather that relatively few have looked on beekeeping as a possible means of livelihood. A better presentation of the subject might serve to overcome this attitude. No effort need be made to induce more people to keep bees: rather an effort might be made to induce half or more of the present bee owners to sell their bees

to good beekeepers in order that the bees might be enabled to produce a crop with the proper care. At present several of the agricultural colleges are maintaining good courses in beekeeping, most of the states have laws providing for the inspection of apiaries to prevent their destruction from infectious diseases and other agencies are assisting in the upbuilding of the industry.

To waste all of this bounteous sugar supply is an economic loss of the first magnitude at any time but never before has this been so forcibly brought home as recently. When the normal sugar supply was reduced people realized as never before the need of a home supply, one not so subject to barbaric ravages on commerce and the perplexities of a restricted production and a more restricted commerce. It is a matter of regret that in 1917 the United States did not save more of the vast store of sugar that is free on every hand. The German nation, with its far-reaching plans for world destruction, had for some years past fostered beekeeping by the giving of bonuses to employees of the national railways if they would engage in beekeeping and similar minor branches of agriculture. We may well pride ourselves that the nation is not dependent on such a means of development but the United States would have been better able to do its share in the war if more attention had been directed to activities such as this.

The entrance of the nation into the war and the shortage of sugar through which part of the country has just passed has wakened an interest in beekeeping, and it is to be hoped that this interest will not lapse when peace is made. Many of the agricultural colleges have begun to urge the better care of bees, the apiary inspectors have assisted in the work, the five journals devoted to beekeeping have rendered valuable service and beekeepers throughout the country have realized more than ever before the need of building up the industry. On the declaration of war the Federal Department of Agriculture began a campaign for increasing the honey crop and the response of beekeepers throughout the country has been most encouraging. It is not the purpose of this article to report what has been done in all lines to bring about this much desired result. An important factor in the increased crop will be the higher price of honey on wholesale markets which has come because of the increased need. It would be difficult to convince beekeepers of this need did not the market prove it to them.

It is desirable, however, to mention one line of activity

which from its nature promises the best results. Mention has been made of the fact that beekeeping is applied animal behavior and that the peculiarity of the beekeeper's work has been a retarding factor in the developing of beekeeping as a commercial industry. Literature does not seem to fill the needs of the case for all the necessary details have been printed in a multitude of forms, as government bulletins and as books. It appears that to an unusual degree personal instruction is needed in making better beekeepers, at least until there are more of them available to act as instructors to others in their communities. The Department of Agriculture has therefore incorporated work in beekeeping in the extension activities and while this work is new and tangible results can not be expected so soon, the interest aroused gives assurance of the good which may be expected from this method of instruction. For the author to urge that extension work in beekeeping is more important than in other lines places him liable to a charge of bias but it is pertinent to point out the greater desirability of personal instruction in these branches of agriculture which involve unusual lines of effort and which are somewhat complex in character. The extension work in beekeeping is small in extent. It has been a difficult task to find available beekeepers who have the necessary equipment in a knowledge of bee behavior and also in the practices of the apiary. There are plenty of beekeepers in the United States who have the requisite training, but the improvement of the honey market, due in no small degree to the light thrown on the subject by the recently organized market news service, has made commercial beekeeping so attractive to those who are equipped for it that few of the properly qualified men have been willing to take up this work and those engaged in the work are taking it up as a patriotic labor. The nature of the extension work and the earnestness of the field men who are doing it give promise for most helpful results in saving for the American people more of the vast store of sugar now so largely wasted. It must not be expected that the honey crop of 1918 will be ten times any previous crop, or even twice as large. Much depends on the season, until such time as better beekeeping makes the crop less dependent on seasonal variation. It is safe to say, however, that patriotic beekeepers from one end of the country to the other will make a greater effort than ever before to do their share. They will be encouraged in this by the realization that they are helping. It will also help them to know that others are interested in their success. They will plan to increase their

apiaries with the assurance that the beekeeping industry has now the best possible opportunity to prove its usefulness and to establish its rightful place among the multitude of agricultural industries. It would be an untrue and even ridiculous assumption to prophesy that beekeeping will result in a reduction in the sugar consumption of the American people, but its growth will enable us to have a larger supply of a sweet which might with profit replace a considerable amount of the jellies, jams and sirups now so widely used. More honey would serve to reduce the consumption of inferior food products for, as beekeepers so often tell each other, it is "Nature's own sweet."

HOG CHOLERA; ITS ECONOMIC IMPORTANCE AND PREVENTION

By Dr. R. R. BIRCH

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EVERY "ultimate consumer" knows that there is an insistent demand for more fats and more meat. Every live-stock breeder knows that the grains that formerly have been used to produce these commodities are commanding prices that well-nigh prohibit their use in meat production. Every live-stock statistician knows that our supply of meat-producing animals is diminishing. And every scientist knows that we must have meats and fats. When these facts are forced to our attention with greater emphasis every day, and when we begin to seek a solution of this one of many problems the war has so suddenly thrust on us, we turn instinctively to the hog. And as with Postum, "There's a reason."

The hog is by far the most economical producer of any of our meat animals. Four or five pounds of dry matter fed to hogs in the form of grain will produce a pound of gain; it requires ten or twelve pounds of dry matter to produce a pound of gain in beef cattle. The fat hog yields almost 80 per cent. of his live weight as dressed carcass; the fat steer dresses only about 60 per cent. of his live weight. In addition to the fact that the hog makes the most of every pound of feed given him, he will eat feed that other animals spurn. City garbage, tankage, small potatoes, and the like, he devours with avidity, converting them promptly into palatable and nutritious human food.

The hog reproduces so rapidly that comparison in this respect with other meat-producing animals leaves us wondering how the latter can survive. A good beef cow bred to-day will have to her credit a year from to-day a calf weighing, at best, three hundred pounds. A good brood sow bred to-day will have to her credit a year from to-day three quarters of a ton of finished pork. If she is bred a second time she will also have to her credit at the end of the year from six to ten pigs such as we roast for Thanksgiving. Speaking in mechanical terms we have rapid acceleration applied both to production and reproduction of swine. In fact, we are not much in error in say-

ing that we have arithmetical progression exemplified in reproduction of beef cattle, and geometrical progression exemplified in reproduction of hogs.

Adding to all these advantages the fact that pork may readily be cured so that it will keep weeks and months at room temperature without deterioration, we have in a nutshell the reasons why the hog still finds a place in intensive farming, in spite of the fact that beef cattle are being crowded out.

But with all the outstanding advantages the hog possesses as a producer of meat, he has one vulnerable point. He contracts hog cholera and dies. True, he is subject to many other diseases that are more or less destructive to him, but hog cholera is his Nemesis. When it attacks one hog in a herd, it usually attacks all, and with the exception of a few stragglers, all succumb. In 1914, the disease cost our nation $75,000,000, killing more than 10 per cent. of its swine population.

In this country, hog cholera appeared first in the Ohio valley, in 1833. Its ravages increased as transportation facilities multiplied, and, as early as 1875, when bacteriology as a science was yet in its infancy, the losses caused by it were so extensive that swine breeders regarded it with universal dread, and it was curtailing, in an alarming degree, America's swine industry.

At this time the science of bacteriology was unfolding a new world. The bacteria, or germs, as they were called, that cause some of the infectious diseases, had been discovered and described, and there was an eager and perhaps hurried search in other directions. Hog cholera, because of its tremendous economic importance, became the object of close and prolonged study, and the researches conducted with this disease are among the most interesting that have occurred in the development of the veterinary sciences.

In 1885, Dr. Elmer Salmon and Dr. Theobald Smith announced that they had discovered the cause of hog cholera, and their findings were corroborated and accepted by trained investigators in this country, and in Europe. This organism (*Bacillus choleræ suis*), a member of the colon group, could be isolated in pure culture from the organs of hogs dead of cholera, it could be grown for generations on culture media, and when these cultures were injected back into other hogs they sometimes caused them to sicken and die. Cultures from the organs of these dead hogs revealed the presence of *Bacillus choleræ suis*, and the incriminating evidence was regarded as complete.

Meanwhile the science of preventive medicine was developing rapidly, and vaccines, serums, and bacterins had sprung into existence. Pasteur had produced vaccines that prevented fowl cholera, rabies, and anthrax, and scientists were eagerly seeking to prevent other infectious diseases in a like manner.

Here again, hog cholera received its share of attention, but all the efforts to produce an effective vaccine by using cultures of *Bacillus choleræ suis* ended in disappointment. Outbreaks of hog cholera still occurred in the field with the same deadly results, and hog raisers still continued to buy nostrums of all descriptions in the forlorn hope of checking the ravages. This state of affairs continued until the close of the nineteenth century, at which time there was a growing belief among some scientists that *Bacillus choleræ suis* was not the real cause of the disease.

This belief was supported by certain facts which will be mentioned presently, and consequently a further search was made for the organism responsible for this disastrous disease. The outcome was that in 1903 de Schweinitz and Dorset of the United States Bureau of Animal Industry announced that it was caused by a filterable virus. This announcement was received with considerable skepticism by those who had followed the long and difficult trail of the *Bacillus choleræ suis*, and who had for eighteen years accepted without doubt its etiological connection with hog cholera. Had not the organism been found repeatedly in the organs of hogs dead of cholera? Had it not been isolated in pure culture and grown in the laboratory for generations? Had not the cultures produced disease and death in hogs to which they were given? Was not the organism found in pure culture in the organs of hogs thus killed? In short, had not *Bacillus choleræ suis* conformed to Koch's dicta?

As a matter of fact it had not wholly, because cultures did not produce disease and death with any degree of regularity. Closer study also revealed the fact that hogs to which the cultures were given did not develop lesions precisely similar to those found in hogs dead in field outbreaks, nor did these artificially infected hogs transmit disease to healthy ones in contact with them. Finally, it was found that hogs artificially infected, and recovered, were not immune to outbreaks of natural infection. Thus there were good reasons to doubt whether *Bacillus choleræ suis* caused hog cholera.

On the other hand, the evidence against the filterable virus was piling higher and higher. Repeated experiments showed

that blood from cholera-infected hogs when passed through fine filters capable of removing all visible bacteria (*Bacillus choleræ suis* included) still remained constantly infectious. More than that, the few hogs that sickened as a result of doses of the filtered blood, and subsequently recovered, were found to be immune to field outbreaks of hog cholera. The mask was at last removed and the filterable virus, after remaining in disguise eighteen years, was revealed to the scientific world as the true cause of hog cholera. Although it did not conform entirely to Koch's dicta, in that it could not be grown in the laboratory, the evidence against it was so conclusive that it was allotted a conspicuous place in the rogue's gallery.

But the filterable virus of hog cholera is found to be far less amenable to the Bertillon system than is *Bacillus choleræ suis*. The latter organism is easily visible with the compound microscope, it grows readily and somewhat characteristically on common culture media, producing gas and acid with a regularity comparable to that observed in chemical reactions. The filterable virus will do nothing of the kind. So far it has refused to grow in any culture medium except the hog; so far it is distinguished by what military men might term "low visibility," at least it is invisible with the strongest microscope; so far its morphological characteristics remain unknown, so it has been placed, in company with others of its stripe, in the pigeon-hole labeled "filterable viruses." Meredith spoke a great truth when he said, "Mankind is the sport of invisible powers."

But after all, what difference does it make how a certain organism behaves in the laboratory if its ravages in the field can be controlled? After numerous baffling attempts directed toward growing the filterable virus artificially, scientists turned their attention toward the latter problem. One fact gave great promise. There was observed an active life-long immunity in hogs that had recovered from hog cholera. Could this immunity safely be produced artificially?

Because the virus could not be grown in the laboratory, vaccines prepared in the usual manner were out of the question. Serum from immune hogs gave disappointing results, but it remained for Dorset, Niles and McBride, of the United States Bureau of Animal Industry, to demonstrate that immune hogs will tolerate enormous doses of blood drawn from hogs sick with cholera, and that subsequently blood from these immunes, or hyperimmunes, as they are called, will prevent cholera in

susceptible swine. This blood became known as anti-hog cholera serum. But the immunity produced proved to be of short duration, unless the hogs treated for protection were exposed to hog cholera near the time at which the serum was administered, so it came to be the practise to produce this exposure by injecting each animal with a small quantity of hog cholera blood at the same time that serum treatment was given. It was found that this produced a lasting immunity, and that it involved but little danger to the animals thus treated.

The product known as anti-hog cholera serum is nothing more than the defibrinated and carbolized blood of hogs that, prior to bleeding, have had their immunity built up by enormous doses of hog cholera blood. Under ordinary circumstances, one cubic centimeter of hog cholera blood will kill a two-hundred-pound susceptible hog, but the immune hog of like size will tolerate a quart of this blood injected into the blood stream.

Anti-hog cholera serum, before being sent into the field for use, is subjected to rigid tests to prove its potency, and when it is carefully prepared it passes these tests with clock-like regularity. It is required to protect hogs given sufficient doses of hog cholera blood to kill them, and exposed, in addition, to natural infection by being placed in a pen with hogs sick with cholera. And it is with a feeling akin to triumph that the serum producer observes his serum-treated hogs surviving the ordeal with no outward signs of disease.

Is hog cholera conquered? Not by any means, but we have in our hands the instrument with which it is possible to conquer it. We can say to any individual breeder with perfect confidence that he does not need to lose his hogs with cholera unless he elects to do so. But our weapon is double-edged, and it is not without flaws in workmanship.

When hogs are treated with serum and virus to produce a permanent immunity, one occasionally sickens, to the extent that he secretes hog cholera virus in his urine. This virus is just as dangerous for other hogs as it would be were the sick hog naturally infected with cholera. In the immediate herd treated this makes no particular difference, because all the hogs are immunized, but new centers of infection may sometimes be produced, from which the virus may find its way to other herds. This danger is greatly augmented when untrained men use serum and virus, and it grew to be so serious that even private serum laboratories, interested in selling as much serum as possible, refuse to sell their products to others than graduate

veterinarians, because they realize that if these products are used by untrained men, they will, in the long run, be discredited.

The danger incident to untrained men in the field is no greater than that due to untrained men in the laboratory. The federal government has recognized this fact, and it now places an inspector in every laboratory that manufactures serum for inter-state shipment. The business of the inspector is to see that the laboratory is kept clean, and that the serum offered for sale is carefully handled and tested.

Even when there is a plentiful supply of potent serum, though, there are various obstacles that militate against its most effective use in the field. It is used as a cure instead of as a preventive, it is used to prevent diseases incorrectly pronounced hog cholera, serum alone is used when both serum and virus are required, and *vice versa*. Each time serum is wrongly used and bad results follow, there is created a certain degree of skepticism regarding its effectiveness.

Added to these obstacles we have constantly with us certain well-meaning but half-informed persons who enthusiastically advise all farmers to have their hogs treated with serum. Such advice is almost equally absurd as would be the order of a fire chief who would direct his men to dash down the street with the chemical wagon, squirting soda and acids indiscriminatingly in all directions, because one house happened to be on fire. Obviously the efforts should be directed at the seat of the trouble, and at points where danger appears imminent. It is also true that unconsciously, perhaps, there has been a certain relaxation in the enforcement of quarantine regulations since hog cholera serum came into use, and the serum has too often been regarded as a substitute for sanitary measures, rather than as an adjunct to them.

What is the attitude of hog raisers toward hog cholera serum? This is an important consideration, because it must ultimately determine success or failure, as far as hog cholera control is concerned. Skepticism prevailed when the discovery was first announced, and even to-day, ten years after that announcement was made, this skepticism is not wholly dispelled. But to those of us who are engaged in the manufacture and use of serum, the wonder is that so much, rather than that so little, progress has been made. Scientists are likely to complain that their devious trails are not closely followed by those whom their efforts are supposed to benefit, and from time to time various educators complain, and too often with justice, of the vast store

of useful knowledge that has received decent burial in books. But Emerson's law of compensation remains always effective, and there is one great advantage associated with the fact that the layman does not follow the scientist too closely. He may meet the scientist coming back.

In the case of hog cholera serum, though, this skepticism, now fast disappearing, has worked great harm to our swine industry, and it has been fostered, not only by certain swine breeders who have to be shown, but by certain "quacks" in the veterinary profession. The doubting farmer is the one who has for years been trying every form of nostrum advertised to prevent or cure hog cholera. The doubting "quack" is the man who has prepared the nostrums.

Nevertheless, it is true that in the great hog-raising states of the Union, there exists to-day no doubt in the minds of progressive hog raisers as to the effectiveness of hog cholera serum. In fact this confidence is so strong that from time to time there arises a short-sighted but insistent demand that hog cholera serum shall be made and distributed free as a

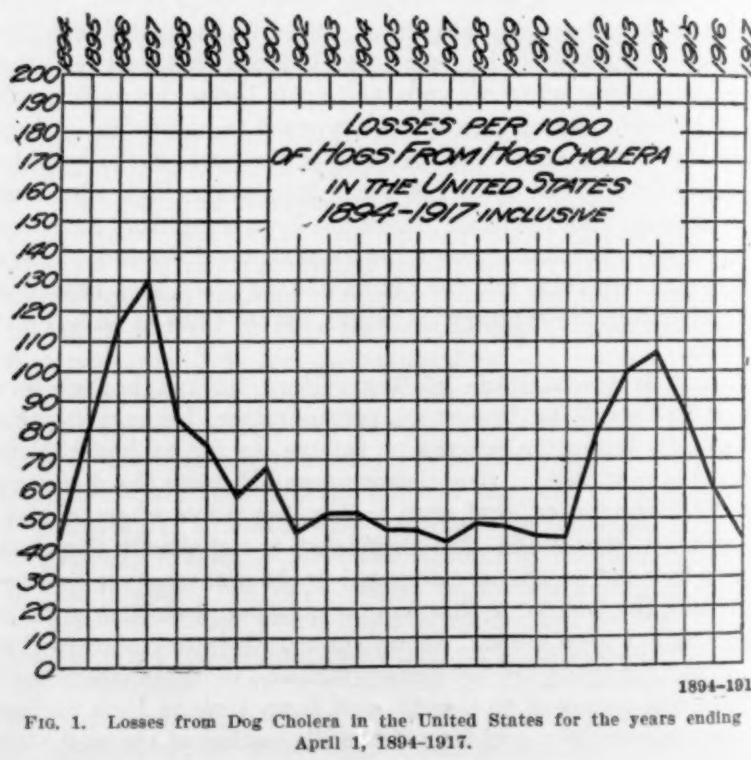

FIG. 1. Losses from Dog Cholera in the United States for the years ending April 1, 1894-1917.

governmental function. This would entail an immense and unnecessary expenditure of public funds, because thousands of doses of serum would then be used without cause, and the supply to meet the legitimate demand would be insufficient. Worse still, serum would be used universally as a preventive of practically every malady that affects swine, and every failure would help to break down confidence in its effectiveness.

What progress is actually being made toward the suppression of hog cholera? One hesitates to quote statistics because one is always reminded of a certain analogy that might be suspected of existing between a person quoting statistics, and the devil quoting Scripture. But I am venturing to include a curve prepared by Dr. J. R. Mohler, chief of the Bureau of Animal Industry, illustrating in graphic form the annual losses from hog cholera throughout a term of years.

If we remember that hog cholera serum came into use in 1908, and if we examine this curve with that fact in mind, we do not at first see much encouragement in the figures presented. But if we remember that during the years when the curve was ascending the facts regarding the effectiveness of hog cholera serum were not generally known, if we remember that its use was but imperfectly understood, if we remember that during those years the supply of serum was far short of the demand, we gain a new understanding of the situation.

Further, when we are told that as far back as 1887, the annual losses from hog cholera reached a proportion of 120 per thousand, and in 1897, a proportion, as the curve shows, of 130 per thousand, we are inclined to believe that the wave whose crest was reached in 1914 was in reality a wave cut short. The downward tendency of the curve since 1914 gives renewed encouragement, but while we must wait several years before we can be sure that this downward direction is maintained, and that it is due to the use of serum, rather than to a normal fluctuation, we believe it can truly be said that out of the misunderstandings and chaos inevitably wrought by a remarkable discovery of his kind, there is steadily and surely being constructed a beaten trail leading to the goal—the complete control of hog cholera.

DOES CROP ROTATION MAINTAIN THE FERTILITY OF THE SOIL?

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FROM time immemorial it has been considered a self-evident fact that where crop rotation is practised there is a bigger and better yield. The farmers of ancient Rome understood that crops following beans, peas and vetches were usually better than those following wheat or barley; but it was not until the last quarter of the nineteenth century that it was learned that the legumes with the aid of associated bacteria has the power of feeding on the free nitrogen of the air, while the non-leguminous plant has not this power and requires a supply of combined nitrogen. To-day we find the best farmers practising some system of crop rotation. They have learned from experience that where crop rotation is practised the crops are bigger and better than where the single crop system is followed. This is usually interpreted as indicating that crop rotation has increased the fertility of the soil. We find many farmers planting legumes for a number of years on rundown soil, each year removing the entire crop and feeling confident that their soil is becoming richer in plant food. Let us examine some of the results which have been obtained in carefully planned experiments to see if this conclusion is warranted by the experimental evidence.

Plants are composed of ten elements, each of which is absolutely essential to their growth and formation. Only two —carbon and oxygen—are secured from the air by all plants, only one—hydrogen—from the water; the other seven are secured by all plants from the soil. One class of plants—the legumes—may, under appropriate conditions, obtain their nitrogen from the air. Six elements—phosphorus, potassium, magnesium, calcium, iron and sulfur—are obtained entirely by the growing plant from the soil.

The great majority of agricultural soils contain large quantities of all these essential elements, with the exception of nitrogen, phosphorus and potassium. These are used by the growing plant in larger quantities than are any of the other elements which are obtained direct from the soil, and in the great major-

ity of soils nitrogen, phosphorus, or potassium is the limiting element in crop production. Therefore our problem resolves itself into the question: Can crop rotation maintain these elements in the soil in quantities sufficient for maximum yields? Phosphorus and potassium are obtained by the growing plant only from the soil; it is, therefore, self-evident that no simple system of crop rotation can maintain the phosphorus and potassium, since the quantity within the soil must of necessity be reduced with each crop removed; the extent depending upon the specific crop grown; hence, nitrogen is the only element which we can hope to maintain by crop rotation. This is the element which is found in the soil in smallest quantity and removed by most plants in larger quantities than the phosphorus or potassium. Moreover, large quantities of this element are at times lost from the soil by leaching, while the loss of the others is comparatively small. It is of the greatest importance, therefore, that nitrogen be supplied to the soils in sufficient quantities for maximum crop production and in the cheapest manner possible. The total quantity of these three elements found in an acre-foot section of two Utah agricultural soils, assuming one acre-foot to weigh 3,600,000 pounds, is given in Table I.

TABLE I. POUNDS PER ACRE OF TOTAL NITROGEN, PHOSPHORUS AND POTASSIUM IN AN ACRE-FOOT OF SOIL FROM THE UTAH GREENVILLE AND NEPHI EXPERIMENTAL FARMS

	Greenville Farm, Pounds per Acre	Nephi Farm, Pounds per Acre
Nitrogen	4,904	3,744
Phosphorus	2,700	8,388
Potassium	60,560	87,840

Both soils contain an abundance of potassium, but the supply of phosphorus and nitrogen is much lower. A study of these results reveals the fact that a fifty-bushel crop of wheat each year for forty-nine years would remove the equivalent of the total quantity of nitrogen in the Greenville soil to a depth of one foot, while a similar crop on the Nephi farm would accomplish this in just thirty-seven years. It would, however, require a fifty-bushel crop 170 years to remove the phosphorus from the Greenville soil and 525 years to remove it from the Nephi soils. Of course a crop would never remove all the nitrogen or phosphorus from a soil, but in actual practise the elements are slowly removed; the crop yields being reduced each year until a certain minimum is reached. When crops can no longer be produced economically then the owner abandons his

soil, moves on to virgin soils, or if it be in an old district he resorts to the expensive commercial fertilizer. The illustration is, however, sufficiently accurate to make it clear that the limiting factor, in so far as soil fertility is concerned in both of these soils, is the nitrogen. And it is true of the great majority of all soils that an increased nitrogen supply means an increased yield. This principle is one of the fundamentals of soil fertility.

Nitrogen exists in the atmosphere in inexhaustible quantities, every square yard of land has seven tons of nitrogen lying over it or if the quantity covering one acre could be combined into the nitrate it would be worth as a fertilizer $125,000,000. Now it has been demonstrated that the legumes—peas, beans, alfalfa, etc.—when properly infected have the power of feeding on this limitless supply of atmospheric nitrogen, while the non-legumes—barley, wheat, oats, etc.—must depend upon the supply within the soil. The farmer should take advantage of this fact to supply nitrogen for his crops, as the commercial fertilizer can not be used economically for the production of most crops, as is seen from the fact that the nitrogen in a 50-bushel wheat crop would cost $14.40, 20 tons of sugar beets $15.00 or one ton of alfalfa hay $7.50 if bought as a commercial fertilizer. But will the legume draw nitrogen from the atmosphere while there is a supply in the soil, or will it follow the line of least resistance and turn only to the atmosphere when nitrogen is lacking in the soil? If it does, it must first drain the soil of its valuable nitrogen and thus leave it no richer than it was before the legume was grown upon the soil. This is the problem which this paper is to answer.

Crop rotation has been practised for centuries, but the oldest system of which we have accurate information is the one on Agdell Field at the Rothamsted Experiment Station. This system was inaugurated in 1848 and is still being carefully followed. It consists of a four-year rotation as follows:

First year—Swede turnips (rutabagas)
Second year—barley
Third year—clover or beans
Fourth year—wheat

Still another system has been running parallel and similar to this, except that fallow cultivation is practised in the third year instead of growing a legume. The average yields for twenty-year periods are given in Table II. These systems are of especial interest to the farmers of Utah, for when we substitute sugar beets for the turnips, and alfalfa or peas for the clover or beans, we have nearly an ideal rotation for our soils.

TABLE II. AVERAGE 20-YEAR YIELDS FROM AGDELL FIELD, ROTHAMSTED STATION

Crop	Legume			Fallow		
	Yield 1st 20 Years, 1848–68	Yield 2d 20 Years, 1868–88	Yield 3d 20 Years, 1888–1908	Yield 1st 20 Years, 1848–68	Yield 2d 20 Years, 1868–88	Yield 3d 20 Years, 1888–1908
Turnips						
Roots pounds	5,264	1,723	967	5,785	3,067	2,502
Leaves pounds	600	447	242	629	538	458
Barley						
Grain, bus.	38.0	22.5	13.7	37.0	22.8	15.9
Straw pounds	2,373	1,496	1,172	2,244	1,489	1,172
Wheat						
Grain, bus.	29.6	21.1	24.3	34.5	23.2	23.5
Straw pounds	3,169	2,082	2,445	3,761	2,420	2,412

Even where the legume was used in the system there has been a decline in the yield. The yield of the turnips during the first twenty years was 5,264 pounds, the second 1,723, and the third only 967 pounds, thus showing a decrease to about one sixth the original in sixty years. The results with the barley are no better, for we find a drop from the fair yield of 38 bushels per acre during the first period to only 13.7 during the third. The wheat which followed the legume in the rotation, and hence occupied the most-favored place in the system, shows a decrease of 5.3 bushels. Not even a good yield has been maintained for the clover, for from 1850 to 1874 the average yield was 4,165 pounds, while from 1882 to 1906 the yield was only 1,246 pounds. In reality we find no greater decline in the yields where fallow cultivation is practised. But both systems strongly testify to the fact that rotation is not maintaining the productive powers of this soil. And the evidence is strong that the legume gets no more nitrogen from the air than that which is removed with the plant. Otherwise we should expect better results in the legume system than in the fallow system.

That the alfalfa, when grown on fertile soil and the crop removed, does not increase the nitrogen of the soil is seen from experiments conducted by Dr. Hopkins at the University of Illinois. The experiment was made possible by the fact that many of the Illinois soils do not normally contain the symbiotic bacteria thus making it impossible for the alfalfa to obtain nitrogen from the air. This being the case, a field was taken which had not grown alfalfa and hence did not contain the symbiotic nitrogen-gathering bacteria. This was planted to alfalfa, only one half of it being inoculated with the legume organism. To some of the plots were added lime and phosphorus to make sure that these were not the limiting factors. The results thus obtained are given in Table III.

TABLE III. FIXATION OF NITROGEN BY ALFALFA IN FIELD CULTURE, ILLINOIS EXPERIMENTS

Plot No.	Treatment Applied	Pounds in Crop		Pounds Nitrogen Fixed by Bacteria
		Dry Matter	Nitrogen	
1*a*.......	None	1,180	21.81	
1*b*.......	Bacteria	2,300	62.04	40.23
2*a*.......	Lime	1,300	26.20	
2*b*.......	Lime bacteria	2,570	68.02	41.82
3*a*.......	Lime phosphorus	1,740	35.40	
3*b*.......	Lime phosphorus bacteria	3,290	89.05	53.65

It is evident from these results that the alfalfa has obtained from 40 to 53 pounds of nitrogen from the air, depending upon the treatment. There was slightly more than one third as much nitrogen in the alfalfa crop from the uninoculated as in the inoculated. Therefore, it is quite evident that the alfalfa in these plots had obtained one third of its nitrogen from the soil and two thirds from the air. Now, nitrogen is required by the root for its growth as well as for the growth above the ground, and we have every reason for believing that the root also would obtain it in the same proportion from air and soil as did the hay crop.

Now, if we examine dry matter and total nitrogen occurring in the roots and stalks of alfalfa, we should be able to decide whether more nitrogen is being returned to the soil in the roots and residues than is removed by the growing plants.

The results for this comparison have been obtained from Illinois and Delaware experiments and are given in Table IV.

TABLE IV. PROPORTION AND COMPOSITION OF TOPS AND ROOTS OF SOME LEGMUES

Legume	Dry Matter per Acre, Pounds	Nitrogen per Acre, Pounds	Per Cent. of Total Nitrogen in Tops
Sweet Clover			
Tops	9,029	174	76
Roots and residues	3,748	54	
Crimson Clover			
Tops	4,512	103	70
Roots........................	2,022	41	
Alfalfa			
Tops	2,267	54.8	60
Roots........................	1,980	40.4	

With the clover three fourths of the total nitrogen is found in the plant above ground and only one fourth in the roots, while the alfalfa shows a greater proportion in the roots—40 per cent. This represents the proportion for the first-year growth for alfalfa and it is not likely that in the older plant this

high proportion of the total nitrogen would be maintained in the roots. It is quite certain that if only two thirds of the total nitrogen of the plant is obtained from the air the quantity returned to the soil with the roots and plant residues does not exceed that removed from the soil by the growing plant, which would give no increase in soil nitrogen from the growing of a legume where the entire crop is removed. And this even where the roots are allowed to remain and decay; yet we find some farmers who remove the roots from the soil and even then expect an increase in their soil fertility.

It is therefore quite certain that the legume, where the crop is harvested, does not increase the soil nitrogen of the fertile soil of Illinois and other soil fairly rich in nitrogen. But what will happen on the arid and semi-arid soil where nitrogen in many cases is the limiting element and is present in much smaller quantities than it is in the soils on which the experiments considered have been conducted. Experiments which have been conducted at the Utah Experiment Station during the last twelve years have demonstrated that even on soils poor in nitrogen the legume first feeds upon the combined nitrogen of the soil. It is known that plant residues and other complex nitrogen compounds found in the soil are transformed by bacteria into ammonia and this in turn by another class of bacteria into nitric nitrogen, and it is mainly on this nitrogen that the growing plant feeds. The quantity of this found in the soil at different periods under different plants has been measured at the Utah Experiment Station and the average results for twelve years are given in Table V.

TABLE V. NITRIC NITROGEN FOUND UNDER VARIOUS CROPS AT DIFFERENT SEASONS OF THE YEAR, POUNDS PER ACRE TO A DEPTH OF SIX FEET

Crop	Spring	Midsummer	Fall	Average
Alfalfa	22.3	15.8	32.8	23.6
Oats	35.7	14.1	20.6	23.5
Corn	24.8	18.9	22.0	21.9
Potatoes	81.1	60.8	54.2	65.3
Fallow	81.5	53.6	62.6	65.9

Here we find the legume alfalfa, removing the nitric nitrogen from the soil just as fast as do the non-legumes. Yet this soil was well inoculated with the symbiotic bacteria which undoubtedly assisted the alfalfa in obtaining free nitrogen from the air when needed, but not until the soluble nitrogen had been drained from the soil to its full extent, as is shown by the fact

that alfalfa soil never contains more than does oats and corn land and is very poor as compared with potato and fallow soil.

It may be argued that the small quantity of nitric nitrogen in the alfalfa soil is due to a lack of its formation, as it is not needed by the legume, hence not formed; but this conclusion is not warranted by the facts in the case, as may be seen from the results obtained where the speed of formation of nitric nitrogen (nitrification) was measured. These also are the average results extending over a number of years and obtained at the Utah Experiment Station.

TABLE VI. MILLIGRAMS OF NITRIC NITROGEN PRODUCED IN 100 GRAMS OF SOIL IN 21 DAYS

Crop	Spring	Midsummer	Fall	Average
Alfalfa	3.15	7.48	3.08	4.56
Oats	2.40	4.00	3.00	3.13
Corn	2.18	3.50	1.48	2.38
Potatoes	3.00	15.55	5.60	8.04
Fallow	1.30	5.50	2.48	3.09

Here we find the quantity of soluble nitrogen produced in the alfalfa soil greater than that produced in either the oat or alfalfa soil, and there is no doubt but that this is one reason why an increased yield is obtained the year following the plowing up of an alfalfa field; for this increased nitrification is noted for several years after an alfalfa field is planted to some other crop. This is due to the alfalfa plant stimulating bacterial organisms of the soil so they make available faster the nitrogen of the soil, but this only depletes the soil of its nitrogen more readily than does the non-legume, for it is the nitrogen already combined in the soil on which the nitrifying organisms act. Hence, we must conclude that alfalfa not only feeds closer on the soluble nitrates of the soil, but it also makes a greater drain upon the insoluble nitrogen of the soil by increasing the nitrifying powers of the soil, and would therefore deplete the soil, if the entire crop be removed, more readily than would other crops, a conclusion which is borne out by the direct analysis of the soil. For the analysis of a great number of Utah soils which have grown various crops for a number of years—some of them having been into alfalfa or wheat for upward of thirty years—revealed the fact that almost invariably the alfalfa soil contained less total nitrogen than did the wheat soil. The average for a great number of determinations made from alfalfa soils was 7,232 pounds per acre of total nitrogen, while

the average for a great number of wheat soils was 7,398 pounds.

These are average results from a great number of determinations made on adjoining alfalfa and wheat soil and they clearly indicate that in ordinary farm practise the alfalfa is making just as heavy a drain upon the soil nitrogen as is the wheat.

Hence, from a consideration of the yields obtained in crop rotation, the relative quantities of nitrogen obtained from the atmosphere and the soil by the alfalfa, the feeding and stimulating effect of the alfalfa upon nitrates, and finally the actual quantity of total nitrogen remaining in the soil after wheat and legumes, we must conclude that the legume does not increase the nitrogen of a common agricultural soil—even in the arid region where the nitrogen is low—when the entire crop is removed.

This conclusion does not, however, mean that crop rotation should not be practised, for there are many reasons why crop rotation commends itself to the careful farmer, but it must not be used and the legume removed with the intention of maintaining soil fertility. This may appear to be an unfortunate conclusion, but it is just the reverse, and if its teachings are heeded it means a fertile soil and an economic gain to the farmer from the system of farming which it requires him to adopt.

There are two practicable methods of maintaining the nitrogen content of the soil. First, planning systems of crop rotations with legumes, the legumes being plowed under and allowed to decay, thus furnishing nitrogen to the succeeding crop. Second, practising a combined system of crop rotation and livestock farming.

Three tons of alfalfa contain 150 pounds of nitrogen, all of which we could assume came from the atmosphere; assuming the quantity found in the roots as coming from the soil. This is the equivalent of the nitrogen found in the grain and straw of seventy-five bushels of wheat. If the alfalfa is plowed under some of the nitrogen would be lost to the growing plant in the processes of decay and leaching, but that the total nitrogen of the soil may actually be increased by the turning under of the legume is certain from field experiments.

The Dominion of Canada Experiment Stations grew mammoth clover for two successive seasons on a soil very low in nitrogen. The two cuttings of mammoth clover with all the residues were turned under each year with the results that the soil gained as an average 177 pounds per acre of total nitrogen which is the quantity of nitrogen found in three forty-bushel

crops of wheat, provided the straw was returned to the soil, as two tons of this contains 20 pounds of nitrogen. On the other hand, work on the soil of the Utah Nephi Experiment Farm, with a rotation of wheat and peas where the peas were plowed under, showed a gain in total nitrogen of 240 pounds in four years. That is, in addition to furnishing the small quantity of nitrogen required by the wheat crop, the peas had added to the soil an average of 60 pounds of nitrogen per year.

The second method of maintaining the nitrogen and organic matter of the soil—the combined rotation and livestock method—is the more practical and if systematically practised will not only maintain the nitrogen of the soil but will prove of great economic value to the individual following it. For it consists of a rotation in which the legume plays a prominent part. The legume to be fed and all the manure returned to the soil: This would mean the selling from the farm the hay crop in the form of butter, milk, or beef which carries from the soil only a fraction of the nitrogen stored by legume; moreover, it brings for the producer much greater returns than does the system in which the legume is completely removed from the soil.

It must, however, be remembered that in this system only about three fourths of the total nitrogen of the feed is recovered in the dung and urine. So that in place of three tons of alfalfa adding 150 pounds of nitrogen to the soil from the air, it would add only 120 pounds and this on the condition that all of the liquid and solid excrements are collected and returned to the soil. But where the alfalfa is to be fed and the manure returned to the soil, the legume can occupy a much longer period in the rotation and that with greater economy than where the legume is to be plowed under directly.

Hence, we find that if these principles which have been established for soils even low in nitrogen be systematically applied it will result in greater revenue from an increased livestock industry and will maintain the soil rich in nitrogen and organic matter in place of depleting it of its stored-up nitrogen, as is so often the case with the present methods.

THE INTERRELATIONS OF ANIMALS AND PLANTS AND THEIR INFLUENCE UPON THE FOOD SUPPLY OF MAN

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CHARLES DARWIN in the "Origin of Species" gives several interesting examples of the "complex relations of all animals and plants to each other in the struggle for existence."[1] One of these is very frequently cited, namely, that of the influence of cats upon the clover crop, since cats catch field mice, and field mice destroy more than two thirds of the bees which are alone instrumental in pollenizing red clover. What will happen when the equilibrium of nature is disturbed by the introduction or extermination of a certain species of plant or animal, is in any case difficult to predict. We know comparatively little about the biological results of changes in the fauna and flora, but certain of the more direct effects of one sort of organism upon the welfare of another in a widely different sphere of life have been carefully worked out. Some of the relations revealed are indeed startling and, economically considered, effectually transpose many apparently harmless organisms into the highly injurious class. Of particular interest at the present time are those relations between organisms that influence the food supply of man.

We are all most familiar with the animals that may be used directly as food. Among these are the domesticated mammals, such as the cattle, sheep and pigs, and mammals that are still wild but have been hunted extensively in the past for food and some of which are still of value in certain localities. Among these are the opossum, the bear, seals, squirrels, rabbits, muskrats, woodchucks, deer, moose, caribou, elk, mountain sheep and mountain goats.

The domesticated birds are only second to the domesticated mammals in food value. Most important of these are the chickens, geese, ducks, guinea fowls, turkeys and pigeons. As among the mammals, there are many wild birds that might form part of our bill of fare, but unfortunately we have in the

[1] "The Origin of Species," 6th edition, 1872, pp. 55–59.

past so thoughtlessly abused this "inexhaustible" natural resource that now the grouse, bobwhites, pheasants, turkeys, wild ducks, wild geese, plovers, snipes and wild pigeons are all but exterminated and are of practically no value to us.

Among the principal reptiles of food value are the turtles, such as the diamond-back terrapin, soft-shelled turtle and green turtle.

The amphibia are of very little importance, furnishing us only frogs' legs. Efforts have been made to carry on frog "farming," but these have not been very successful in close quarters, because the frogs eat each other, and their food, of small animals, can be obtained for them only with difficulty.

Fish, on the other hand, have been for centuries one of man's most abundant food resources, and both the federal and state governments are now expending large sums to plant new waters or to restock depleted fishing grounds.

Shellfish, likewise, have figured strongly on human bills of fare from the days of primitive man to the present time. Oysters have been particularly favored. Other shellfish that are commonly eaten by human beings are the soft-shell clam, razor-shells, hen clams, mussels and scallops. Certain large snails are considered a delicacy, especially by the French, and squids are eaten by some people, particularly the Chinese and Italians.

The sea serves as a pasture for many species of edible Crustacea. Of these the most important are the lobsters, blue crabs, and shrimps. Freshwater crayfishes are not used as extensively as food, but the growing scarcity of lobsters makes it probable that raising crayfishes for market may soon become a flourishing industry.

It is evident from the above list that man has in the past been indebted for much of his food supply to wild animals, which have come to him with no more effort than that required to capture and distribute them, and this list has been presented simply to remind us of the extent of our indebtedness to them.

Not only are many kinds of animals used directly as food by man, but certain of them manufacture food products that we would greatly miss if we were deprived of them, such as milk, butter, cheese, eggs and honey.

Each of these food animals has its own particular part to play in the struggle for existence, and its value to us makes its enemies our enemies. Among the most conspicuous destructive animals are the predacious mammals. The relations

of predacious mammals to other animals and to man are very complex and each species must be examined separately in order to determine its economic status. Space allows us, however, only room for a few general statements. Where uninfluenced by the presence of man, a balance is struck between these flesh-eaters and the herbivorous animals upon which they prey. Often their activities are of real benefit, since vast numbers of rabbits, mice and other harmful species are destroyed by them. The more important predacious mammals are the wolf, coyote, mountain lion, bear, lynx, fox and mink. The wolf is particularly destructive in localities where domesticated animals are reared in large numbers. Lack of their natural food, which formerly consisted of wild game, principally bison, has decreased their numbers almost to the vanishing point, and the relentless war waged upon them by man has all but exterminated them. Wolves and coyotes also have beneficial qualities, since they destroy prairie dogs, ground squirrels and other harmful rodents, but these are far outweighed by their destruction of wild game and domesticated animals. Mountain lions kill deer, young elk and other food animals. The bear and lynx are too rare to be of much importance; the fox and the mink prey upon both wild and domesticated birds, but often pay for their depredations by destroying obnoxious insects, field mice, ground squirrels and rabbits.

Less conspicuous than the predacious mammals, but of greater economic importance, are the parasitic organisms, most of which are very small, but none the less effective. Mention may be made of the threadworms, such as syngamus, which causes the disease known as gapes in poultry and game birds; and the stomach worm of the sheep; of the tapeworms, such as that of the dog, which spends part of its growth period lodged in the brain of certain food mammals—they cause "gid" or "staggers" in sheep; of the liver fluke which likewise attacks sheep; and of several extremely minute species belonging to the lowest group in the animal kingdom—the protozoa. Of the last named, one of the most important is the microscopic organism that causes Texas-fever in cattle. The life history of this organism may well serve as an illustration of the interrelations of animals widely separated in the animal series. The fever organisms or germs live in the blood corpuscles of sick cattle. They are often sucked into the bodies of ticks which infest these cattle, and after multiplying for a time, some of them become lodged in the eggs of the tick. These eggs are laid on the ground and the young germ-infested ticks that emerge from

them cling to grass blades or weeds waiting for cattle to brush against them. When this happens they fasten themselves to the animal's body and begin to suck their blood. Some of the fever germs are injected into the blood of the victim during this attack and Texas-fever in due time results. Thus this apparently insignificant organism aided by an apparently harmless tick causes an annual loss of about sixty million dollars to the people living in the fever district and a corresponding decrease of our food supply.

The control of the Texas-fever tick is very simple. The adult ticks die after laying their eggs, and the young die if they do not gain access to cattle within a few months. A pasture may thus be freed from ticks if left vacant for a few months. Ticks may also be removed from cattle by dipping the animals in vats containing substances such as crude petroleum or arsenical mixtures which kill the ticks.

Animals that destroy or lessen the value of food plants and their products are frequently overlooked. Every one who has attempted to raise garden vegetables or fruit knows what constant attention is necessary to prevent potato beetles, squash bugs, San José scales, codlin moths and other insects from preventing a harvest. So numerous and varied are these insects that the general impression arises that all insects are injurious. This however is far from true, since many parasitic species cause the death of countless harmful ones, and in fact, by holding the latter in check, are responsible for preventing the production of such mighty hordes of greedy pests that we are actually saved from starvation by their efforts.

For example, the minute tachina flies really make it possible for us to raise grain in many localities, since they destroy enormous numbers of army worms. The army worm is a black and yellow striped caterpillar about one and one half to two inches long when full-grown. It is the young of an inconspicuous dull-brown moth. Sometimes these caterpillars become so numerous that they are forced to migrate in search of food, like a foraging army. Crops over large areas are eaten by the worms with tremendous loss to the farmer and indirectly to the food-consuming public. Fortunately the tachina flies increase as rapidly as the army worms which they parasitize. Their eggs are laid on the body of the worms and the young that hatch from them burrow into their hosts, finally killing them.

Other insects are, like the bumble bee, responsible for the pollinization of flowers and consequently the production of seed.

The dependence of plants upon pollinization by insects is well illustrated by the Smyrna fig. Prior to the year 1900 this fig could not be grown in the orchards of California, but since then the causes have been found, and the remedy applied with satisfactory results. The figs did not ripen because their flowers were not pollinized. When pollination was found to be accomplished by a minute insect, this insect was introduced into the fig-growing districts of California and a successful new industry established.

Rivaling in interest the establishment of the fig industry in California is that of the salvation of the orange and lemon trees of the same origin. Kellogg gives the facts in this case in the following words:

> In 1868 some young orange trees were brought to Menlo Park (near San Francisco) from Australia. These trees were undoubtedly infested by the fluted scale which is a native of Australia. These scale immigrants throve in the balmy California climate, and particularly well probably because they had left all their native enemies far behind. By 1880 they had spread to the great orange-growing districts of southern California, five hundred miles away, and in the next ten years caused enormous loss to the growers. In 1888 the entomologist Koebele, recommended by the government division of entomology, was sent at the expense of the California fruit growers to Australia to try to find out and send back some effective predacious or parasitic enemy of the pest. As a result of this effort, a few Vedalias were sent to California, where they were zealously fed and cared for, and soon, after a few generations, enough of the little beetles were on hand to warrant trying to colonize them in the attacked orange groves. With astonishing and gratifying success the Vedalia in a very few years had so naturally increased and spread that the ruthless scale was definitely checked in its destruction, and from that time to this has been able to do only occasionally and in limited localities any injury at all.

The relations of birds to insects are known to most every one, but we can not mention too often or emphasize too strongly their influence in maintaining the equilibrium in the insect world. Much of the trouble now encountered by gardeners, horticulturists, and farmers would vanish if we could only bring back the birds that have been killed for food or driven away by various agents controlled by man, such as the domestic cat.

The decision as to what attitude to take toward any particular wild animal is indeed a difficult one. Whether to encourage it by protection or to eliminate it by paying a bounty for its capture is often a puzzling question. Among the birds the great horned owl occupies a doubtful position, sometimes being considered decidedly harmful, at other times neutral, and even beneficial. The owl feeds principally on birds and mam-

mals, and less frequently on insects. The birds are mostly game birds and poultry. There can be, of course, no doubt regarding its injurious character so far as this part of its bill of fare is concerned since all these birds are decidedly beneficial. On the other hand its mammalian food consists largely of rodents, such as mice, ground squirrels and rabbits, and an occasional skunk. Mice, ground squirrels and rabbits are among the most destructive gnawing animals, whereas the skunk may be destructive if it acquires a taste for poultry and the habit of robbing birds' nests, or it may be beneficial, feeding largely on insects and mice. Judgment regarding the great horned owl, therefore, becomes largely a matter of opinion and the conclusion is perhaps justified that in such cases it is best to regulate the number of individuals so that no notable destruction ensues. In the case of the owl, no effort is necessary since almost every hunter and farmer's boy shoots an owl on sight and thus their numbers are kept down to a minimum.

Among the many apparently useless animals that are really indispensable for the proper production of our food supply are the minute swimming animals, the Crustacea, of which the water flea is an example, and the lowly earthworm.

Although the Crustacea used as food by man in the United States are valued at several millions of dollars annually, still their indirect value as food for fish is probably greater. The smaller Crustacea furnish perhaps the principal item in the fish's bill of fare. They are extremely abundant everywhere; at one time there may be more than 250,000 in a single cubic yard of lake water or of sea water. Their effect upon the abundance of mackerel has recently been studied with the following results: The number of fish depends upon the number of Crustacea that are available for food. These Crustacea feed upon minute plants, mostly diatoms, that float about near the surface of the sea, and their abundance must depend upon the abundance of these plants. The plants require sunlight for their growth and multiplication, so that the amount of sunlight controls the number of plants. Actual observations have shown that a season of bright sunshine is followed by good fishing, and a cloudy one always results in a poor catch of mackerel.

Charles Darwin, in his book on the "Formation of Vegetable Mold through the Action of Worms," has shown, by careful observations extending over a period of forty years, how great is the economic importance of earthworms. One acre of ground may contain over fifty thousand earthworms. The

feces of these worms are the little heaps of black earth, called "castings," which strew the ground, being especially noticeable early in the morning. Darwin estimated that more than eighteen tons of earthy castings may be carried to the surface in a single year on one acre of ground, and in twenty years a layer three inches thick would be transferred from the subsoil to the surface. By this means objects are covered up in the course of a few years. Darwin speaks of a stony field which was so changed that "after thirty years a horse could gallop over the compact turf from one end of the field to the other, and not strike a single stone with its shoes."

The continuous honeycombing of the soil by earthworms makes the land more porous and insures the better penetration of air and moisture. Furthermore the thorough working over of the surface layers of earth helps to make the soil more fertile.

The need for a more detailed knowledge of such interrelations as above cited has long been recognized by the experts of the United States Department of Agriculture and by others, since there is still much to be learned. One who investigates this subject even superficially soon learns how wasteful we have been of our inexhaustible (?) resources of food animals and also of animals that protect our plants and animals from their natural enemies. May we not hope that among the benefits that we may derive from the conditions in which the world finds itself at present will be a realization of how dependent we are upon wild animals for our food supplies, and how important it is that steps should be taken for their conservation.

TWILIGHT IN THE ADIRONDACKS.

A Habitat Group of Virginia Deer installed in the American Museum of Natural History, by Hobart Nichols, A.N.A., showing the beautiful results now obtained in museum exhibits.

THE PROGRESS OF SCIENCE

THE ARMORED DINOSAUR

Recently there has been placed on exhibition in the United States National Museum, at Washington, the mounted skeleton of an armored dinosaur on which science has bestowed the name *Stegosaurus*. The skeleton as exhibited (see Fig. 7, reproduced here from a photograph of the specimen) measures 14 feet 9 inches long and stands about 8 feet high from the ground to the top of the highest plate. The bones of this specimen were discovered in southeastern Wyoming, a region long famous for the many and well-preserved fossil specimens found there. Although collected more than thirty years ago, it is now exhibited to the public for the first time.

The Stegosaurs were by reason of their large size and ornate bony skin structures the more striking and characteristic of the large reptilia that inhabited the Northern Hemisphere in the long-past ages. It should be stated, however, that this family is not confined exclusively to North America, for specimens have been found in England, France and German East Africa that are but little unlike the American representatives.

At this time the origin of the family is not known, though it is now generally believed that they were descended from a bipedal ancestry and that increasing bulk and development of the dermal armor caused them to lose celerity of movement, thus becoming sluggish, slow-moving creatures of low mentality. By measurement of the brain cavity in the skull of *Stegosaurus* it is found that the brain displaces but 56 cubic centimeters of water, with an estimated weight of about 2½ ounces. This small organ directed the movements of a creature estimated to weigh several tons, whereas the average normal human brain has a capacity of 900 cubic centimeters in a

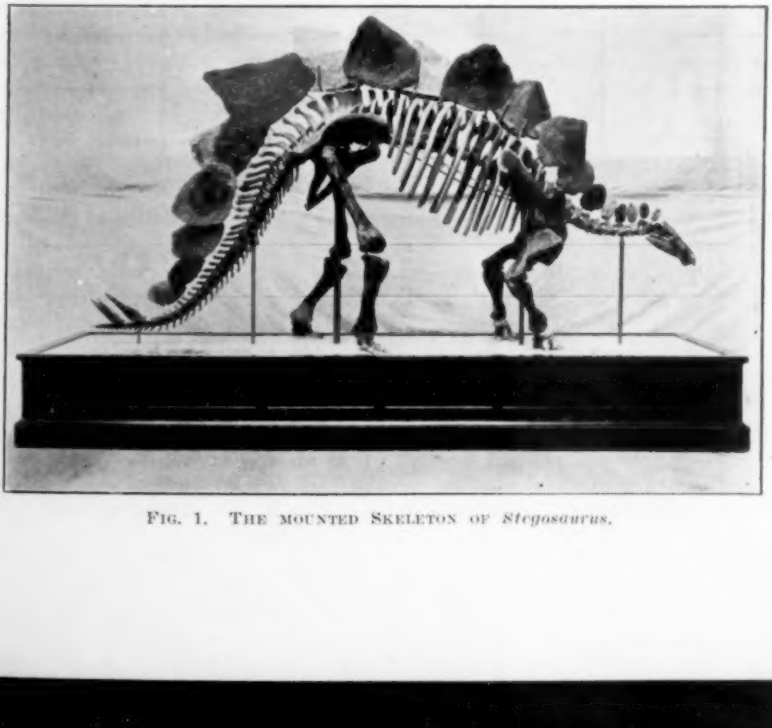

Fig. 1. The Mounted Skeleton of *Stegosaurus*.

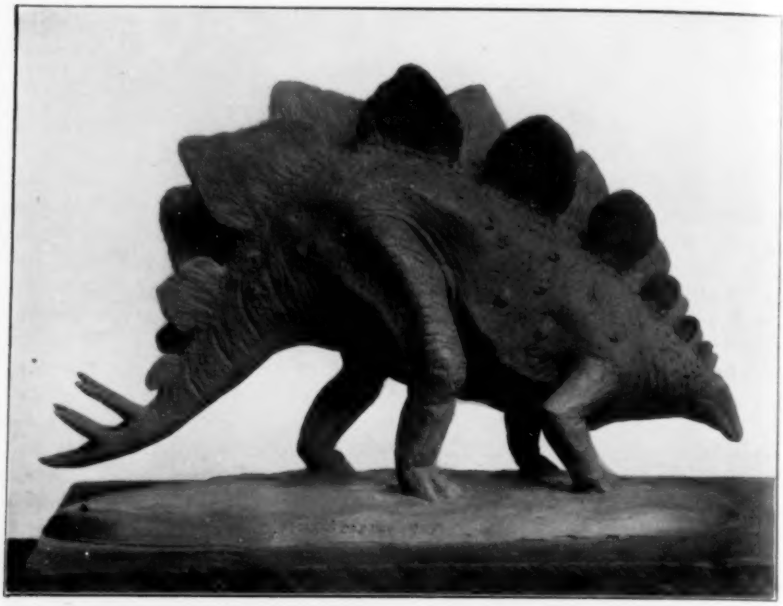

FIG. 2. RESTORATION OF *Stegosaurus*.

creature weighing from 130 to 150 pounds.

The most remarkable feature of the nervous system of this great brute, however, is the enormous enlargement of the spinal cord in the sacral region, which has a mass of more than 20 times that of the puny brain. At best the intelligence of this animal was of the lowest order, hardly more than sufficient to direct the mere mechanical functions of life. Whereas the great horned dinosaurs with skulls from 7 to 9 feet long were the largest-headed land animals the world has ever known, the Stegosaurs are the smallest-headed when the great bulk of the body is taken into consideration. The jaws are provided with a dentition made up of teeth so small and weak as to be always a source of wonder and conjecture as to the real character of their feeding habits. It would at least appear to indicate that their food consisted of the most succulent of terrestrial plants.

The structure of the large, broad feet suggests they were land haunting, doubtless of low, swampy regions rather than the upland, and such an environment would be most suitable for furnishing the soft plant life necessary for their sustenance.

In addition to the small head, the great difference in the proportions of the fore and hind legs, the one most striking external feature of *Stegosaurus* is the unusual development of the skin armor, consisting as it does of two parallel rows of erect alternating bony plates extending from back of the skull on either side of the midline of the back to the end of the tail, the tail being armed near the tip with two pairs of bony spikes or spines. There are also a considerable number of small rounded bony ossicles that in life were held in the skin and probably formed a mail-like protection to the head and neck. The primary purpose of this armor must have been for defense, protective to the extent of giving the animal a most for-

midable appearance rather than actually useful as defensive instruments.

While the fossil remains of these animals are not uncommon in our museums, they consist for the most part of the scattered and disarticulated bones of the skeleton, the present specimen being the only mounted skeleton of this animal on exhibition at this time.

In Fig. 2 is shown a model restoration of *Stegosaurus* prepared by the writer and which portrays his conception of the life appearance of this animal. In this restoration is incorporated all the latest evidence relating to its external appearance, and it is thought to give a fairly accurate picture of the living animal. The recent discoveries of skin impressions with the fossil remains of other dinosaurian specimens makes it not unreasonable to expect that *Stegosaurus* had a scale-like integumentary covering, instead of the smooth elephant-like skin as here depicted. In the light of these recent discoveries we may yet hope to have still more definite knowledge as to its true nature.

CHARLES W. GILMORE

THE SULPHUR SITUATION IN THE UNITED STATES

A PUBLICATION of the U. S. National Museum under the title "Sulphur: An Example of Industrial Independence," by Joseph E. Pogue of the Division of Mineral Technology, presents in a simple and non-technical manner the striking aspects of one of the most interesting mineral industries in our country to-day. A feature of value is a series of halftone plates, made not only from actual photographs of mining operations, but also from several views of a miniature model-reproduction of a typical sulphur mine, with the underground disposition of the sulphur exposed to sight, so reproduced as to give the appearance of bird's-eye or aeroplane view of both occurrence and mining.

At the outbreak of the war in 1914, the United States was producing each year about 350,000 tons of sulphur, valued at a little over $6,000,000. This quantity was sufficient to supply not only the needs of this country, but contributed about 100,000 tons to European markets. With the development of war activities, however, the production has increased to meet the growing needs of munition makers, while the exports have decreased as a result of disturbed trade conditions and the need for building up reserves of this essential material at home.

It is a singular fact that the chief raw materials of explosive manufacture are localized in a remarkable manner, and sulphur is no exception to this rule. In the United States practically the entire supply comes from a number of deposits in Louisiana and Texas near the Gulf Coast. These deposits are similar in nature and consist of a series of beds and lenses of pure sulphur at a depth of several hundred feet from the surface.

The discovery of the occurrence of sulphur of this type was made as far back as 1865, in connection with a well drilled for oil. All attempts at mining the sulphur failed, however, until some fifteen years ago, when a highly ingenious method was devised for winning this substance without recourse to the ordinary costly underground operations usually prosecuted in mining. This process makes use of the fact that sulphur melts at a relatively low temperature. By drilling a well through the overlying rock until the sulphur bed is tapped and then sinking a series of interpenetrating pipes through which superheated steam is forced, the sulphur is melted and forced to the surface as a hot liquid, where it is piped

to large bins, into which it pours and cools. This process, which is known as the Frasch process after its inventor, has been described as one of the triumphs of modern technology, and its successful application to the Gulf Coast deposits has in the past fifteen years transferred the center of the world's sulphur industry from the island of Sicily to the United States, making our nation absolutely independent of the rest of the world in this important particular.

With the development of the world war, the sulphur deposits of the Gulf Regions have, of course, assumed special importance as supplying the sulphur needed in the manufacture of gunpowder and other explosives. But in addition to this, these deposits have quite unexpectedly during the past few months been able to meet and solve a critical resource problem arising out of the submarine campaign. This problem concerned the raw materials of the large and very vital sulphuric-acid industry, and arose from the fact that most of the several million tons of sulphuric acid used in this country was made from a sulphur-bearing mineral called pyrite, brought as ballast in quantity from large deposits in Spain. The restricted shipping conditions resulting from recent events as a matter of course seriously affected this source of supply, and since sulphuric acid is a product nearly as fundamental to industry as iron or coal, the situation bade fair to assume critical proportions. But it so happens that crude sulphur under emergency can also be used in making sulphuric acid, and accordingly the Gulf sulphur deposits have come forward to tide over the dearth of Spanish pyrite until the domestic supplies of pyrite, which are adequate but as yet only in part developed, can be brought up to a suitable measure of productiveness.

There are numerous lean deposits of sulphur in many of the western states, but these as yet have practically no effect upon the output of the country. It is therefore certain that without the Gulf deposits and the ingenious method of making them available, this country would have scarcely been able to meet successfully the war needs of sulphur and sulphuric acid; which goes to show, of course, the pressing necessity for widespread appreciation and understanding of the importance of proper development of the mineral industries of our nation.

WAR WORK OF THE U. S. COAST AND GEODETIC SURVEY

THE steamers *Surveyor*, *Isis* and *Bache*, of the Coast and Geodetic Survey, their crews and 38 commissioned officers of the survey have been transferred to the Navy Department, and 29 commissioned officers and 10 members of the office force have been transferred to the War Department with military rank corresponding to their grade in the survey.

In conformity with the wishes of the Navy Department, after the beginning of the war all of the topographic, hydrographic and wire-drag work of the survey was directed so as to meet the most urgent military needs of the Navy Department. The work done comprises wire-drag surveys on the New England coast and coast of Florida; hydrographic surveys on the South Atlantic coast and Gulf of Mexico; the beginning of a survey of the Virgin Islands; the investigation of various special problems for the Navy Department; wire-drag surveys, current observations, and special work on the Pacific coast; and surveys in the Philippine Islands.

The work undertaken for the War Department by the field parties of the Coast and Geodetic Survey was intended to furnish points

and elevations for the control of topographic surveys for military purposes. To expedite this work an allotment was made from the appropriation for the War Department to cover the expenses of the field parties employed. The chief of the division of geodesy was authorized to confer with officers of the Corps of Engineers, United States Army, and officials of the Department of the Interior in regard to the proper coordination of the various operations.

Extensive surveys were undertaken, including primary triangulation, primary traverse, precise leveling and determination of differences of longitude, and good progress has been made, and the results of previous surveys have been made available by copies or in published form as promptly as possible. From April, 1917, to January, 1918, 80 per cent. of the time of the office force of the geodetic division was devoted to war work.

RECONSTRUCTION OF CRIPPLED SOLDIERS

Surgeon-General Gorgas has issued a recommendation that hereafter no member of the military service disabled in line of duty, even though not expected to return to duty, will be discharged from service until he has attained complete recovery or as complete recovery as it is to be expected that he will attain when the nature of his disability is considered. The inauguration of this continued treatment will result, during the period of the war, in the saving to the service of a large number of efficient officers and soldiers who without it would never become able to perform duty. Physical reconstruction is defined as the completest form of medical and surgical treatment carried to the point where maximum functional restoration, mental and physical, has been secured. To secure this result the use of work, mental and manual, will be required during the convalescent period. This therapeutic measure, in addition to aiding greatly in shortening the convalescent period, retains or arouses mental activities, preventing "hospitalization," and enables the patient to be returned to service or civil life with the full realization that he can work in his handicapped state, and with habits of industry much encouraged if not firmly formed.

At each hospital where reconstruction work is carried on there will be a special "educational" officer, whose functions are to arrange for and supervise, under the direction of the commanding officer of the hospital, the means provided for the use of therapeutic work, such as curative workshops, classes, etc.; to act as technical adviser to the commanding officer on this subject; to recommend the development of necessary means to keep patients employed so far as it is possible to do so; to make the necessary records of work done in his department; and to have immediate charge of any special training of vocational nature which can be given with the means at hand.

These officers are to be obtained from the ranks of teachers, vocational instructors and others especially qualified, and will be selected for their training, experience and peculiar fitness for the work. Where it is possible a man will be obtained who is himself handicapped by some physical disability and who has made a success in life.

As a result of a survey made by the Surgeon-General's Office of men already undergoing reconstruction treatment in this country, it is expected that enlisted men who have completed their treatment and retraining, but who are unfitted for further field service, will be found worthy of commissions and well

fitted for the work outlined in the two preceding paragraphs. No increase in the number of enlisted men in the Medical Department is anticipated for this work, the expectation being that patients, or former patients, will be used.

SCIENTIFIC ITEMS

WE record with regret the death of Ewald Hering, the eminent physiologist, professor at Leipzig; of G. A. Lebour, professor of geology at the University of Durham, and of C. I. Istrati, professor of chemistry at Bucharest.

DR. WILLIAM WALLACE CAMPBELL, director of the Lick Observatory, University of California, has been elected a foreign member of the Royal Society.—Professor Russell H. Chittenden, director of the Scientific School of Yale University, Professor Graham Lusk, of the Cornell Medical School and Mr. John L. Simpson, of the United States Food Administration, have been representing the United States at the inter-allied food conference in Paris.

THE annual meeting of the National Academy of Sciences was held at the Smithsonian Institution in Washington on April 22, 23 and 24. The program included accounts of war activities in different branches of science and reports of the results of several important scientific researches by members of the academy and others. The Hale lectures were given by Professor John C. Merriam, of the University of California. His subject was "The beginnings of human history from the geologic records."—The American Philosophical Society held its annual general meeting at Philadelphia on April 18, 19 and 20. Dr. William B. Scott, professor of zoology at Princeton University, presided, succeeding Dr. W. W. Keen, who after ten years of distinguished service would not permit himself to be reelected. The general lecture was given by Lieutenant-Colonel R. A. Millikan, whose subject was "Science in relation to the war." On the afternoon of April 20, there was a symposium on "Food-problems in relation to the war."